
**NEVADA TEST SITE
2007 WASTE MANAGEMENT MONITORING REPORT
AREA 3 AND AREA 5 RADIOACTIVE WASTE
MANAGEMENT SITES**

June 2008

Prepared for:

U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office

Prepared by:

National Security Technologies, LLC
Las Vegas, Nevada

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EXECUTIVE SUMMARY

Environmental monitoring data were collected at and around the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs) at the Nevada Test Site. These data are associated with radiation exposure, air, groundwater, meteorology, vadose zone, subsidence, and biota. This report summarizes the 2007 environmental data to provide an overall evaluation of RWMS performance and to support environmental compliance and performance assessment (PA) activities. Some of these data (e.g., radiation exposure, air, and groundwater) are presented in other reports (National Security Technologies, LLC, 2007a; 2008; Warren and Grossman, 2008).

Direct radiation monitoring data indicate exposure levels at the RWMSs are at background levels. Air monitoring data at the Area 3 and Area 5 RWMSs indicate that tritium concentrations are slightly above background levels. A single gamma spectroscopy measurement for cesium was slightly above the minimum detectable concentration, and concentrations of americium and plutonium are only slightly above detection limits at the Area 3 RWMS. The measured levels of radionuclides in air particulates are below derived concentration guides for these radionuclides. Radon flux from waste covers is well below regulatory limits. Groundwater monitoring data indicate that the groundwater in the uppermost aquifer beneath the Area 5 RWMS is not impacted by facility operations. The 136.8 millimeters (mm) (5.39 inches [in.]) of precipitation at the Area 3 RWMS during 2007 is 13 percent below the average of 158.1 mm (6.22 in.), and the 123.8 mm (4.87 in.) of precipitation at the Area 5 RWMS during 2007 is 6 percent below the average of 130.7 mm (5.15 in.). Soil-gas tritium monitoring at borehole GCD-05U continues to show slow subsurface migration consistent with previous results. Water balance measurements indicate that evapotranspiration from the vegetated weighing lysimeter dries the soil and prevents downward movement percolation of precipitation more effectively than evaporation from the bare-soil weighing lysimeter. Data from the automated vadose zone monitoring system for the operational waste pit covers show that evaporation continues to slowly remove soil moisture that came from the heavy precipitation in the fall of 2004 and the spring of 2005. The vegetated final mono-layer cover on the U-3ax/bl disposal unit at the Area 3 RWMS effectively removes moisture from the cover by evapotranspiration. During 2007, there was no drainage through 2.4 meters (8 feet) of soil from the Area 3 drainage lysimeters that received only natural precipitation or were vegetated but water drained from the bare-soil Area 3 drainage lysimeter that received 3 times natural precipitation. Elevated tritium levels in plants and animals sampled from the Area 3 and Area 5 RWMSs show tritium uptake by the biota, but the low levels of other radionuclides do not suggest that there has been intrusion into the waste.

All 2007 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility PAs.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGL	above ground level
AMSL	above mean sea level
ARL/SORD	Air Resources Laboratory, Special Operations and Research Division
BJY	Buster-Jangle Y
BN	Bechtel Nevada
°C	degrees Celsius
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
Ci	curie
cm	centimeter(s)
DCG	Derived Concentration Guide
DOE	U.S. Department of Energy
E	evaporation
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
ET _{ref}	reference evapotranspiration
°F	degrees Fahrenheit
ft	feet; foot
GCD	greater confinement disposal
in.	inch(es)
km	kilometer(s)
LLW	low-level waste
μCi/m ³	microcuries per cubic meter
m	meter(s)
MDC	minimum detectable concentration
MEDA	Meteorological Data Acquisition
mi	mile(s)
mm	millimeter(s)
mph	mile(s) per hour
mrem/yr	millirem per year
m/s	meter(s) per second(s)
m ³	cubic meters
NTS	Nevada Test Site
NSTec	National Security Technologies, LLC
PA	Performance Assessment

pCi/m ³	picocuries per cubic meter
RREMP	Routine Radiological Environmental Monitoring Plan
RWMS	Radioactive Waste Management Site
SC	specific conductance
TDR	time-domain reflectometry
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides
VWC	volumetric water content

1.0 INTRODUCTION

This document summarizes the calendar year 2007 waste management environmental monitoring data for the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs). Characterization reports for the Area 3 RWMS (National Security Technologies, LLC [NSTec], 2007b) and the Area 5 RWMS (Bechtel Nevada [BN], 2006b) provide descriptions of each RWMS including location, setting, waste disposal operations, and monitoring programs. These reports also provide brief summaries of characterization and monitoring data. The Integrated Closure and Monitoring Plan for the Area 3 and Area 5 Radioactive Waste Management Sites at the Nevada Test Site (BN, 2005c) identifies the regulatory requirements and describes the intended approach for closing and monitoring the RWMSs after waste disposal is finished. This report summarizes environmental data, as briefly defined below.

- Direct radiation monitoring conducted to confirm that RWMS activities do not result in significant exposure above background levels.
- Air monitoring conducted to confirm that RWMS activities do not result in significant radionuclide concentrations above background levels and confirm compliance with National Emission Standards for Hazardous Air Pollutants.
- Groundwater monitoring conducted, as required by U.S. Environmental Protection Agency (EPA) regulations and U.S. Department of Energy (DOE) orders, to assess the water quality of the aquifer beneath the Area 5 RWMS and to confirm that Area 5 RWMS activities are not affecting the aquifer.
- Vadose zone monitoring conducted to assess the water balance of the RWMSs, confirm the assumptions made in the Performance Assessments (PAs) (including no downward pathway), and evaluate the performance of operational monolayer-evapotranspirative waste covers.
- Soil-gas monitoring for tritium conducted to evaluate tritium movement at waste containment cell GCD-05U.
- Biota monitoring for tritium and other radionuclides conducted to evaluate the upward pathway through the waste covers.
- Subsidence monitoring conducted to ensure that subsidence features are repaired to prevent the development of preferential pathways through the covers.

These data are collected by NSTec, as required by various DOE orders and regulations from the Code of Federal Regulations (CFR). For a detailed description of these regulatory drivers, refer to the Integrated Closure and Monitoring Plan (BN, 2005c). These regulatory drivers exist to mitigate risk to the public and environment and include the following:

- DOE Order 435.1, "Radioactive Waste Management"
- DOE Order 450.1, "Environmental Protection Program"
- DOE Order 5400.1, "General Environmental Protection Program"

- DOE Order 5400.5, "Radiation Protection of the Public and the Environment"
- Title 40 CFR 61, "EPA: National Emission Standards for Hazardous Air Pollutants"
- Title 40 CFR 264, "EPA: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"
- Title 40 CFR 265, "EPA: Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities"

Environmental monitoring data are collected and analyzed as per Quality Assurance, Analysis, and Sampling Plans which can be found in the Nevada Test Site Routine Radiological Environmental Monitoring Plan (RREMP) (BN, 2003). The RREMP was written with a Data Quality Objectives-driven process to identify what and how technically defensible environmental monitoring data are collected.

2.0 SITE DESCRIPTIONS

2.1 AREA 3 RWMS

The Area 3 RWMS is located on Yucca Flat within the Nevada Test Site (NTS). Yucca Flat is an elongated, sediment-filled basin that trends roughly north-south; the long axis extends approximately 27 kilometers (km) (17 miles [mi]), and the short axis extends approximately 16 km (10 mi). Yucca Flat is bound by Quartzite Ridge and Rainier Mesa on the north, the Halfpint Range on the east, the Massachusetts Mountains and CP Hills on the south, and Mine Mountain and the Eleana Range on the west (Figure 2-1). The Yucca Flat basin slopes from the north at an elevation of approximately 1,402 meters (m) (4,600 feet [ft]) above mean sea level (AMSL) to the south toward Yucca playa, with the lowest part of the basin at an elevation of approximately 1,189 m (3,900 ft) AMSL. The Area 3 RWMS elevation is 1,223 m (4,012 ft). Yucca Flat was one of several primary underground nuclear test areas, and much of the length of the valley is marked with subsidence craters (NSTec, 2007b).

The unsaturated zone at the Area 3 RWMS is estimated to be approximately 488 m (1,600 ft) thick (BN, 1998), and the water table is assumed to occur in Tertiary tuff. The alluvium thickness is estimated between 370 and 460 m (1200 and 1500 ft) (BN, 2005b).

Typical daily air temperatures vary from -5 degrees Celsius (°C) (23 degrees Fahrenheit [°F]) to 11°C (52°F) in winter and from 15°C (59°F) to 37°C (98°F) in summer. Based on a 27-year record (1981–2007) from location Buster-Jangle Y (BJY) (4.5 km [2.8 mi] northwest of the Area 3 RWMS), the maximum observed temperature is 44°C (112°F) and the minimum is -20°C (-4°F). Based on a 47-year record (1961 to 2007) from location BJY, the average annual precipitation is 163.7 millimeter (mm) (6.44 inches [in.]) (Air Resources Laboratory, Special Operations and Research Division [ARL/SORD], 2008). During 2007, the temperature ranged from -15.1°C (4.8°F) to 41.5°C (106.7°F), and precipitation was measured at 136.8 mm (5.4 in.) at the Area 3 RWMS. Precipitation is highly variable at the Area 3 RWMS. The standard deviation of the 11-year record of annual precipitation is 91.5 mm (3.60 in.); the maximum annual precipitation was 374.1 mm (14.73 in.) in 1998 and the minimum was 26.2 mm (1.03 in.) in 2002. Annual reference evapotranspiration (ET_{ref}) at the Area 3 RWMS, calculated using local meteorology data, is approximately 10 times annual average precipitation (Desotell et al., 2007).

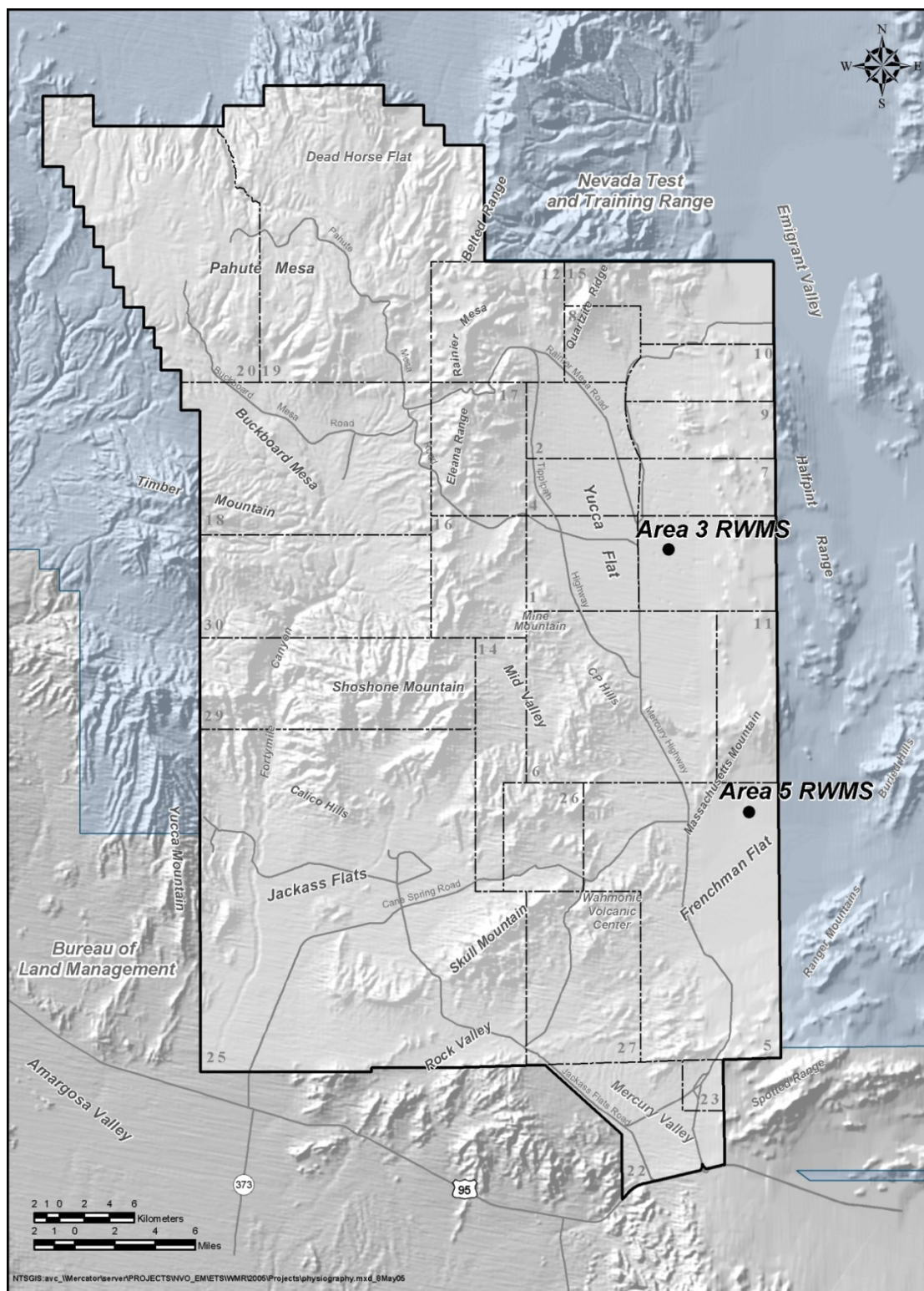


Figure 2-1 Locations of the Area 3 and Area 5 RWMSs at the NTS

2.2 AREA 5 RWMS

The Area 5 RWMS is located on northern Frenchman Flat at the juncture of three coalescing alluvial fan piedmonts (Snyder et al., 1995). Frenchman Flat is a closed intermontane basin located in the southeastern portion of the NTS. Frenchman Flat is bound by the Massachusetts Mountains and the Halfpint Range on the north, the Buried Hills on the east, the Spotted Range on the south, and the Wahmonie Volcanic Center on the west (see Figure 2-1). The valley floor slopes gently toward a central playa (BN, 2006b). Ground surface elevations range from 938 m (3,077 ft) AMSL at the playa to over 1,220 m (4,003 ft) AMSL in the nearby surrounding mountains. The Area 5 RWMS elevation is 962 m (3,156 ft).

The thickness of the unsaturated zone at the Area 5 RWMS is 235.8 m (774 ft) at the southeast corner of the RWMS (Well UE5PW 1), 256.6 m (842 ft) at the northeast corner (Well UE5PW 2), and 271.5 m (891 ft) to the northwest of the RWMS (Well UE5PW 3). Wells UE5PW 1 and UE5PW 2 penetrate only alluvium, while Well UE5PW 3 encounters tertiary tuff at a depth of approximately 189 m (620 ft) (BN, 2005a). The water table beneath the Area 5 RWMS is extremely flat. The average groundwater elevation measured at these wells is 733.7 m (2,407 ft) AMSL.

Typical daily air temperatures vary from about 5°C (23°F) to 11°C (52°F) in winter and from 17°C (62°F) to 39°C (103°F) in summer. Based on a 27-year record (1981–2007) from location Well 5B (6.4 km [4 mi] south of the Area 5 RWMS) the maximum observed temperature is 46°C (115°F) and the minimum is -21°C (-6°F). Based on a 45-year record (1963–2007) from location Well 5B, the average annual precipitation is 124.9 mm (4.92 in.) (ARL/SORD, 2008). During 2007, the temperature ranged from -14.7°C (5.5°F) to 43.9°C (111.0°F), and precipitation measured 123.8 mm (4.87 in.) at the Area 5 RWMS. Precipitation is highly variable at the Area 5 RWMS. The standard deviation of the 13-year record of annual precipitation is 64.0 mm (2.52 in.); the maximum annual precipitation was 258.9 mm (10.19 in.) in 1998 and the minimum was 37.7 mm (1.48 in.) in 2002. Annual ET_{ref} at the Area 5 RWMS, calculated using local meteorology data, is approximately 13 times the annual average precipitation (Desotell et al., 2006).

Areas 3 and 5 are similar, except for slight differences in air temperature, precipitation, and soil texture. Area 3 receives approximately 30 percent more rainfall than Area 5, the annual average temperature at Area 3 is about 2°C (4°F) cooler than at Area 5, and soils at Area 3 are generally finer grained than those at Area 5.

2.3 HYDROLOGIC CONCEPTUAL MODEL OF THE AREA 3 AND AREA 5 RWMS

Climate and vegetation strongly control the water movement in the upper few meters of alluvium at both RWMSs. The magnitude and direction of both liquid and vapor fluxes vary seasonally and often daily. Except for periods following precipitation events, water content values in the near-surface are quite low. Below the dynamic near-surface is a region where relatively steady upward water movement is occurring. In this region of slow upward flow, stable isotope compositions of soil pore water confirm that evaporation (E) is the dominant process (Tyler et al., 1996). The upward flow region extends to depths from approximately 3 to 49 m (10 to 160 ft) in Area 3, and from approximately 3 to 40 m (10 to 131 ft) in Area 5. Below the upward flow region, water potential measurements indicate the existence of a static region. The static region is between approximately 49 and 119 m (160 to 390 ft) deep in Area 3, and between approximately 40 and 90 m (131 to 295 ft) deep in Area 5 (Shott et al., 1997; 1998). In the static region, essentially no vertical liquid flow is currently occurring. Below the static region,

flow is steady and downward due to gravity (Figure 2-2). Stable isotope compositions of pore water from these depths indicate that infiltration into this zone occurred under cooler past climatic conditions (Tyler et al., 1996). If water were to migrate below the current static zones, movement to the groundwater would be extremely slow due to the low water content of the alluvium. Estimates of travel time to the groundwater (assuming zero upward flux), based on hydraulic characteristics of the alluvium, and assuming that current conditions would still apply, are in excess of 500,000 years in Area 3 (Levitt and Yucel, 2002) and 50,000 years in Area 5 (Shott et al., 1998).

Based on the results of extensive research, field studies, modeling efforts, and monitoring data which are summarized in the Area 3 and Area 5 Performance Assessments (PAs) (Shott et al., 1997; 1998; Levitt et al., 1999; Levitt and Yucel, 2002; Desotell et al., 2006), groundwater recharge is not occurring under current climatic conditions at the RWMSs. Studies indicate that under bare-soil conditions, such as those found at the operational waste cell covers, some drainage may eventually occur through the waste covers into the waste zone. This drainage is estimated to be about 8 percent of the annual rainfall at Area 5, based on one-dimensional modeling results (Desotell et al., 2006).

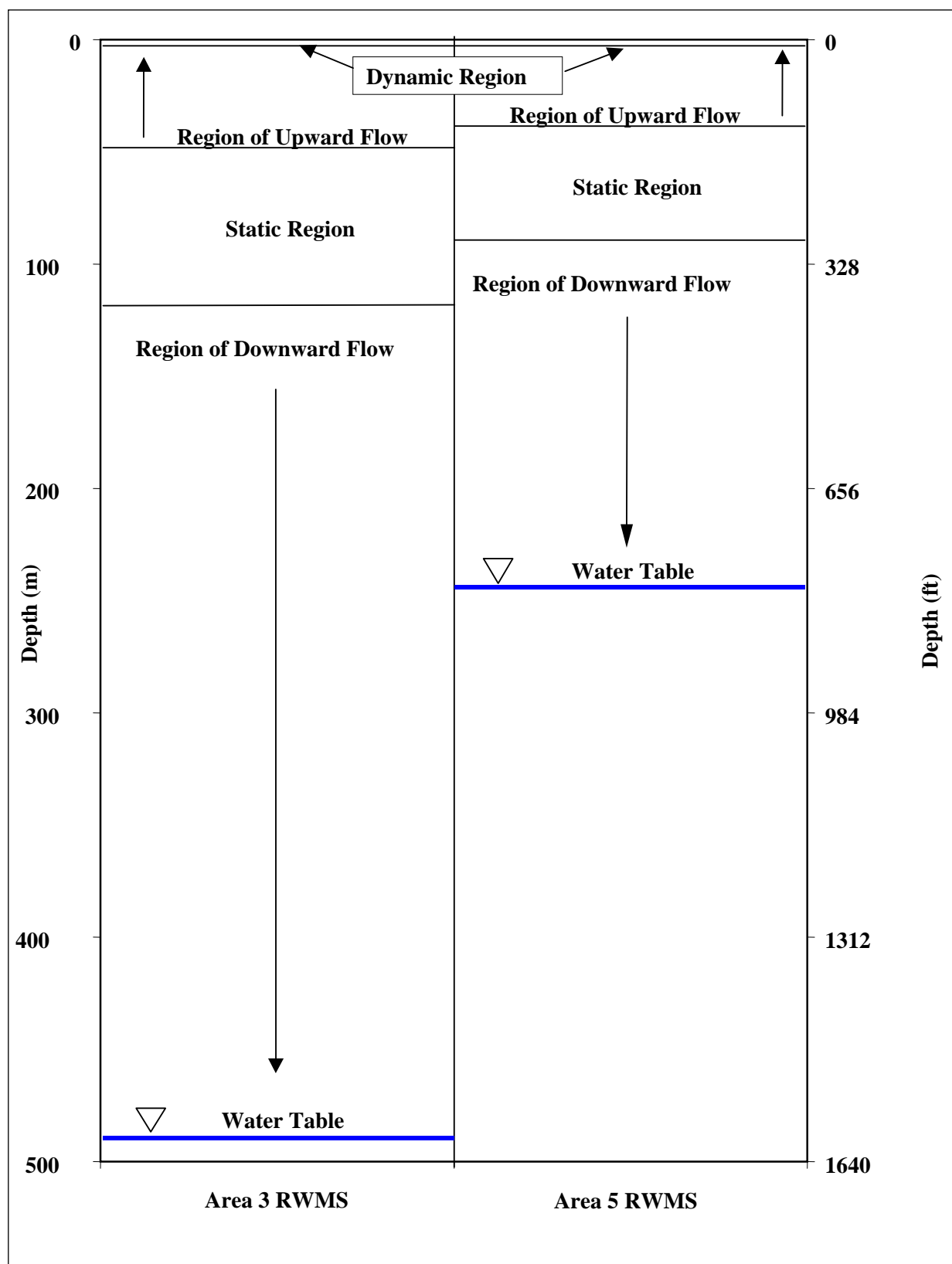


Figure 2-2 Vadose Zone Hydrologic Conceptual Models of the Area 3 and Area 5 RWMSs

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3.0 PROJECT DESCRIPTION

The Area 3 and Area 5 RWMSs are designed and operated for the disposal of radioactive low-level waste (LLW) and mixed waste that is generated on site (at the NTS), from DOE offsite locations, and from other approved offsite generators.

3.1 AREA 3 RWMS

Waste disposal cells within the Area 3 RWMS are subsidence craters resulting from underground nuclear testing. The seven craters within the Area 3 RWMS ranged from 122 to 177 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth at the time of formation (Plannerer, 1996). Disposal in the U-3ax crater began in the late 1960s; disposal began in U-3bl in 1984. Waste forms consisted primarily of contaminated soil and scrap metal, with some construction debris, equipment, and containerized waste. Craters U-3ax and U-3bl were combined to form the U-3ax/bl disposal unit (Corrective Action Unit [CAU] 110), which is now covered with a vegetated, native alluvium, evapotranspiration (ET) cover that is at least 2.4 m (8 ft). For details of the final closure plan of CAU 110, refer to BN (2001). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at has been used for disposal of bulk LLW from the NTS and approved offsite generators. Crater U-3bh was originally used for disposal of contaminated soils from the Tonopah Test Range in 1997 and has been used since for waste disposal from other approved generators. The remaining two craters are not in use (Figure 3-1). For a detailed description of the facilities at the Area 3 RWMS, refer to Shott et al. (1997) and NSTec (2007b).

3.2 AREA 5 RWMS

Waste disposal has occurred at the Area 5 RWMS since the early 1960s. The Area 5 RWMS consists of 32 landfill cells (pits and trenches) and 13 greater confinement disposal (GCD) boreholes (Figure 3-2 and Figure 3-3). Some previous documents list fewer landfill cells, but new cells continue to be constructed and Trench 4 was separated into T04C and T04C1 (BN, 2005c). Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). The unlined disposal units receive sealed waste containers. Containers are stacked to approximately 1.2 m (4 ft) below original grade and soil backfill is pushed over the containers in a single layer to a thickness of approximately 2.4 m (8 ft) thick. For a detailed description of the facilities at the Area 5 RWMS, refer to Shott et al. (1998). For further descriptions of pits, trenches, and GCD boreholes, refer to BN (2005c; 2006b) and Cochran et al. (2001).

There are currently seven pits receiving waste at the Area 5 RWMS. The open pits include P03U, P06U, P12C, P13U, P14U, P15U, and P16C. The only active mixed waste disposal cell is P03U. All other active units contain LLW except P06U, which contains asbestiform LLW. Construction of P17U began in 2007, but no waste has been disposed in P17U. Landfill cells that have been operationally closed to date include all 16 trenches and 9 pits. The nine closed pits are P01U, P02U, P04U, P05U, P07U, P08U, P09U, P10C, and P11U.

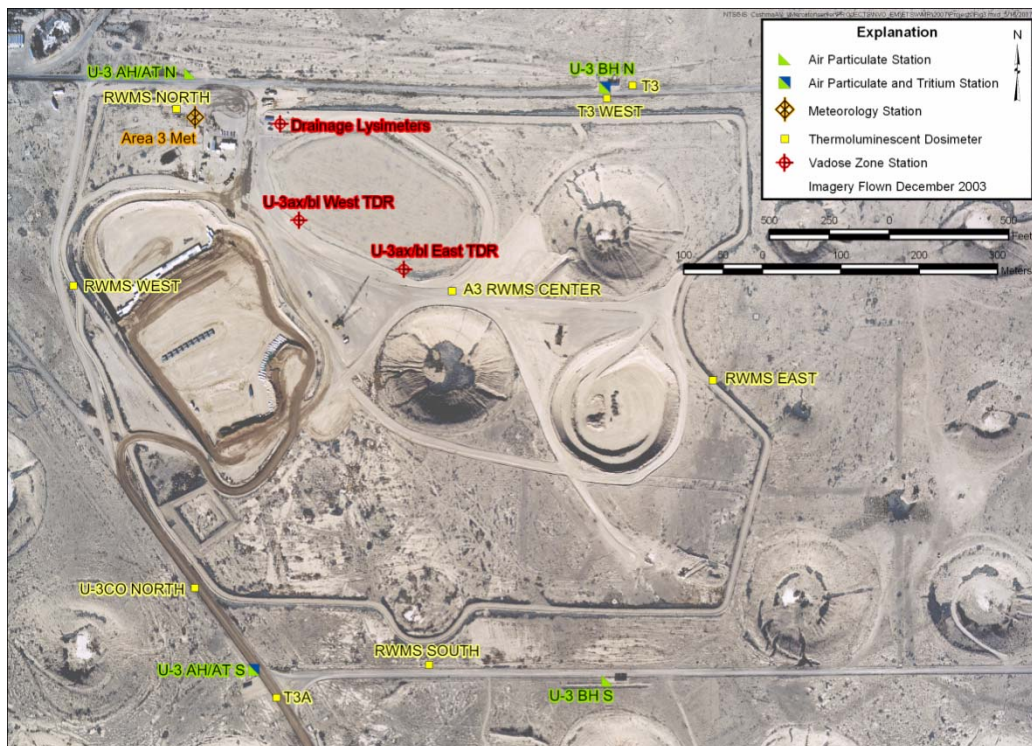


Figure 3-1 Monitoring Locations at the Area 3 RWMS

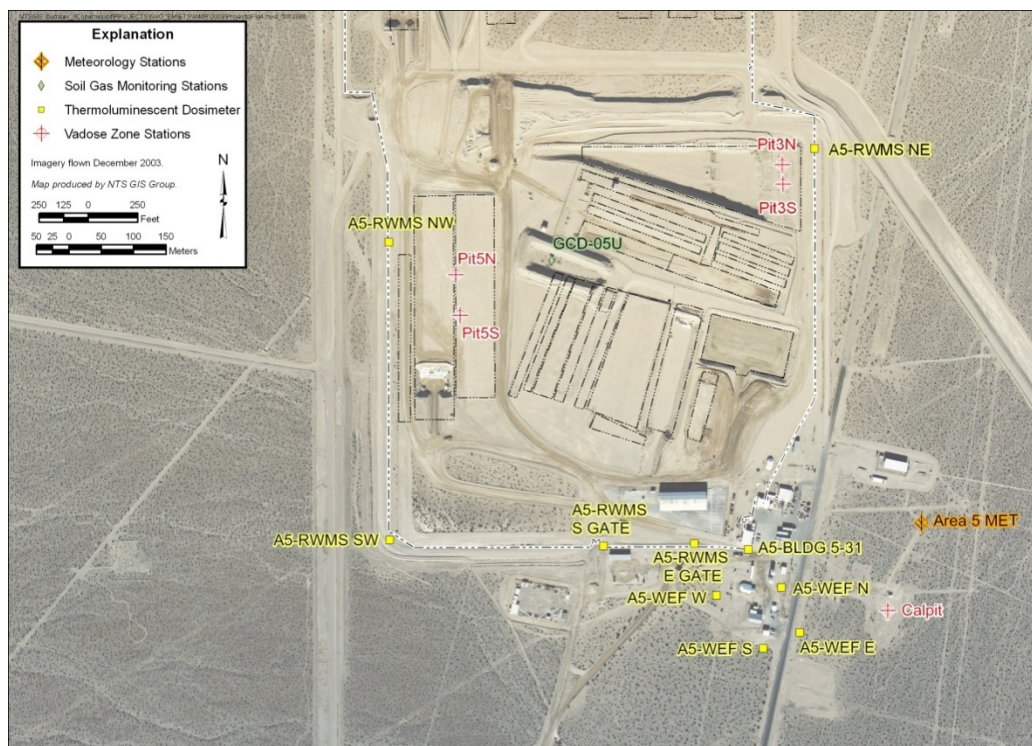


Figure 3-2 Monitoring Locations at the Area 5 RWMS

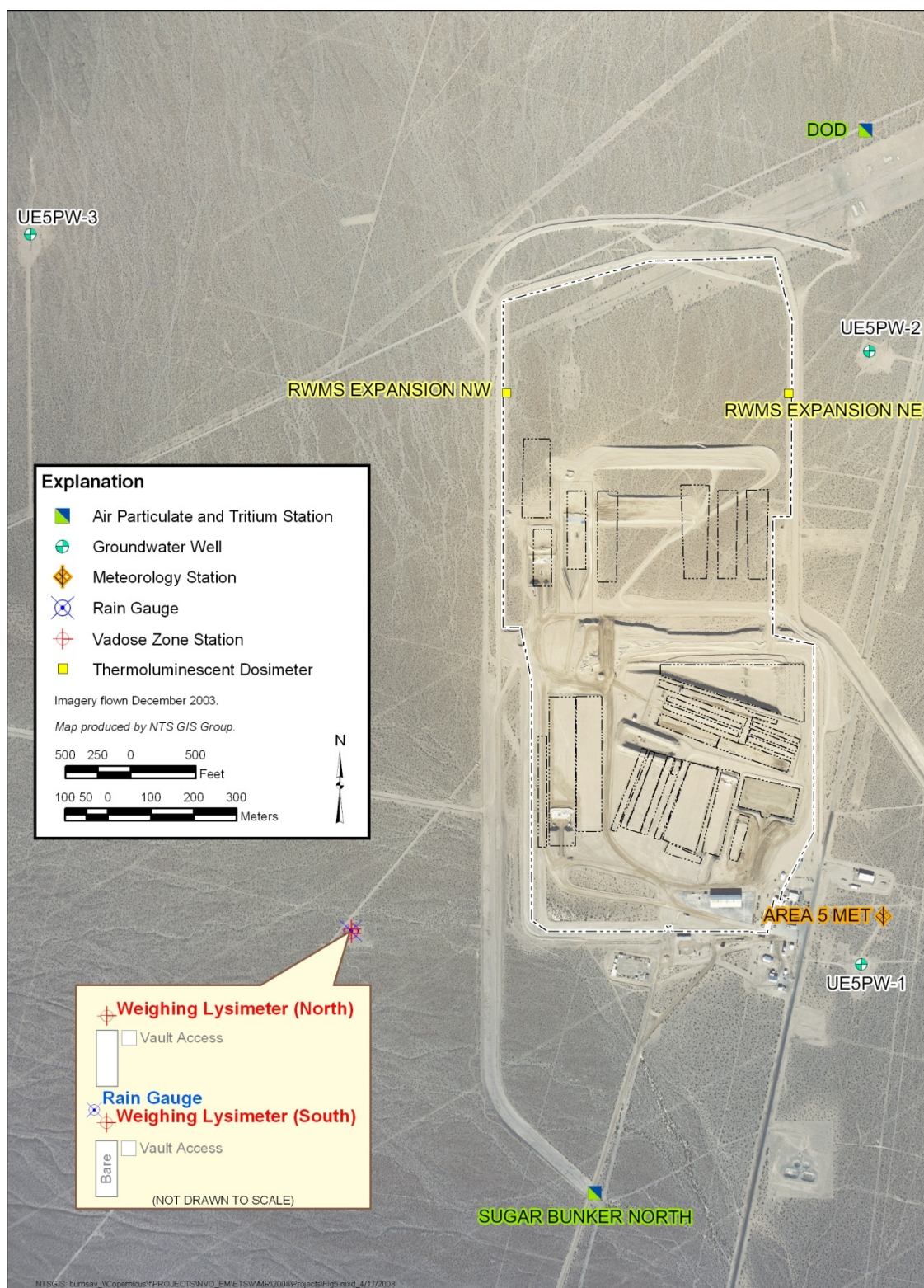


Figure 3-3 Locations of the Pilot Wells, Weighing Lysimeter Facility, and Air Monitoring at the Area 5 RWMS

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4.0 ENVIRONMENTAL MONITORING DATA

4.1 TYPES OF ENVIRONMENTAL MONITORING DATA

Area 3 RWMS monitoring locations are shown in Figure 3-1, and Area 5 RWMS monitoring locations are shown in Figure 3-2 and Figure 3-3. This report provides a general description and graphical representations of some of these data. Monitoring data currently being collected include:

- Radiation Exposure Data
 - Quarterly thermoluminescent dosimeter (TLD) measurements
- Air Monitoring Data
 - Weekly Data
 - Alpha concentrations
 - Beta concentrations
 - Biweekly Data
 - Tritium concentrations
 - Monthly Data
 - Gamma concentrations
 - Americium (Am) concentrations
 - Plutonium (Pu) concentrations
 - Periodic radon flux measurements from waste covers
- Groundwater Monitoring Data
 - Quarterly Water-Level Measurements
 - Semiannual Indicators of Contamination
 - pH (field measurement)
 - Specific conductance (SC) (field measurement)
 - Total organic carbon (TOC)
 - Total organic halides (TOX)
 - Tritium
 - Semiannual General Water Chemistry Parameters
 - Total calcium, iron, magnesium, manganese, potassium, sodium, silicon
 - Total sulfate, chloride, fluoride
 - Alkalinity
 - Biennial RREMP Analyses
 - Gross alpha
 - Gross beta
 - Gamma spectroscopy
 - Plutonium (^{238}Pu and $^{239+240}\text{Pu}$)
 - Triennial RREMP Analyses for Specific Radionuclides
 - Strontium (^{90}Sr)
 - Technetium (^{99}Tc)
 - Carbon (^{14}C)

- Meteorology Monitoring Data
 - Daily Meteorology Data
 - Average air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) above ground level (AGL)
 - Maximum air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Minimum air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Maximum relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Minimum relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Maximum wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average barometric pressure
 - Maximum barometric pressure
 - Minimum barometric pressure
 - Total precipitation
 - Hourly Meteorology Data
 - Average air temperature at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average relative humidity at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average wind speed at 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average wind direction 3.0 m (9.8 ft) and 9.5 m (31.1 ft) AGL
 - Average barometric pressure
 - Average solar radiation
 - Total precipitation
- Vadose Zone Monitoring Data
 - Annual Soil Gas Monitoring Data (soil gas tritium concentrations measured at GCD-05U gas sampling ports [nine depths])
 - Weighing Lysimeter Data (Area 5)
 - Daily and hourly E from the bare-soil weighing lysimeter
 - Daily ET from the vegetated weighing lysimeter
 - Soil volumetric water content (VWC), soil water potential, and temperature with depth
 - Daily Drainage Lysimeter Data (Area 3)
 - Soil VWC, soil matric potential, and temperature with depth
 - Drainage
 - Total soil water storage
 - Daily Automated Vadose Zone Monitoring System Data
 - Soil VWC with depth in waste covers
 - Soil VWC beneath waste cells
 - Soil matric potential with depth in waste covers
 - Soil temperature with depth in waste covers
- Periodic Subsidence Monitoring Data: locations and description of subsidence features on waste covers
- Biota Monitoring Data: periodic analysis of plant and animal samples for tritium and other radionuclide concentrations

4.2 RADIATION EXPOSURE DATA

The goals of direct radiation monitoring are to assess the state of the external radiation environment, detect changes in that environment, and measure gamma radiation levels near potential exposure sites. Performance objectives in DOE Order 435.1 state that LLW disposal facilities shall be sited, designed, operated, maintained, and closed so it is reasonable to expect that the total effective dose equivalent from all exposure pathways, except the dose from radon, to representative members of the public shall not exceed 25 millirem/year (mrem/yr). Because the RWMSs are located well within the NTS boundaries, no members of the public have access to these areas for significant periods of time. However, exposure rates measured by TLDs located at the RWMSs show the potential external dose to a hypothetical person residing year-round at the RWMS.

TLDs are used to measure ionizing radiation exposure from all sources, including natural and man-made radioactivity. The Panasonic UD 814AS TLD is used and consists of four elements housed in an air-tight, water-tight, ultraviolet-light-protected case. A slightly shielded lithium borate element is used to check low-energy radiation levels, and an average of three calcium sulfate elements are used to measure penetrating gamma radiation.

Figure 3-1, Figure 3-2, and Figure 3-3 show TLD monitoring locations. At each location, a pair of TLDs is placed at 1 ± 0.3 m (28 to 51 in.) AGL and are exchanged for analysis on a quarterly basis. Quarterly TLD analysis is done using automated TLD readers that are calibrated and maintained by the NSTec Radiological Control Department. TLD response was scaled using reference TLDs exposed to 100 milliroentgen from a cesium-137 (^{137}Cs) radiation source under controlled conditions.

Between 1952 and 1972, 60 nuclear weapons tests were conducted within 400 m (1,312 ft) of the Area 3 RWMS boundary. Fourteen of these tests were atmospheric tests that left radionuclide-contaminated surface soil and, therefore, elevated radiation exposures across the area. Waste pits in the Area 3 RWMS are subsidence craters from seven subsurface tests that are being filled with LLW. During disposal operations, the waste is covered with clean soil resulting in lower exposures inside the Area 3 RWMS, compared with the average exposures at the fence line or in Area 3 outside the fence line.

Annual radiation exposures during 2007 at locations inside and near the Area 3 RWMS are shown in Figure 4-1. RWMS Center is inside the Area 3 RWMS; RWMS North, RWMS East, RWMS South, and RWMS West are at the RWMS boundary; and T3, T3 West, T3A, and U-3CO North are outside the RWMS (see Figure 3-1). The exposures measured inside the Area 3 RWMS and three of four measurements at the boundary were within the range of background exposures. The TLD locations outside the Area 3 RWMS boundary and RWMS South (boundary location) have higher exposures due to their proximity to historic aboveground nuclear weapon test locations. Given this, current Area 3 RWMS operations have contributed negligible external exposure to a hypothetical person residing at the Area 3 RWMS boundary during 2007. Direct radiation exposure data from 1998 to 2007 at the Area 3 RWMS and NTS background locations are presented in Figure 4-2.

Between 1951 and 1971, 25 nuclear weapons tests were conducted within 6.3 km (3.9 mi) of the Area 5 RWMS. Of these, 15 were atmospheric tests; 9 of the remaining 10 tests released radioactivity to the surface, which contributes to exposures in the area. No nuclear weapons testing occurred within the boundaries of the Area 5 RWMS. During 2007, estimated annual

exposures from TLD measurements at the Area 5 RWMS were within the range of exposures measured at NTS background locations (Figure 4-3).

Direct radiation exposure data from 1998 to 2007 from the two RWMSs and NTS background locations (Figure 4-2 and Figure 4-3) indicate that direct radiation exposure is generally low or declining.

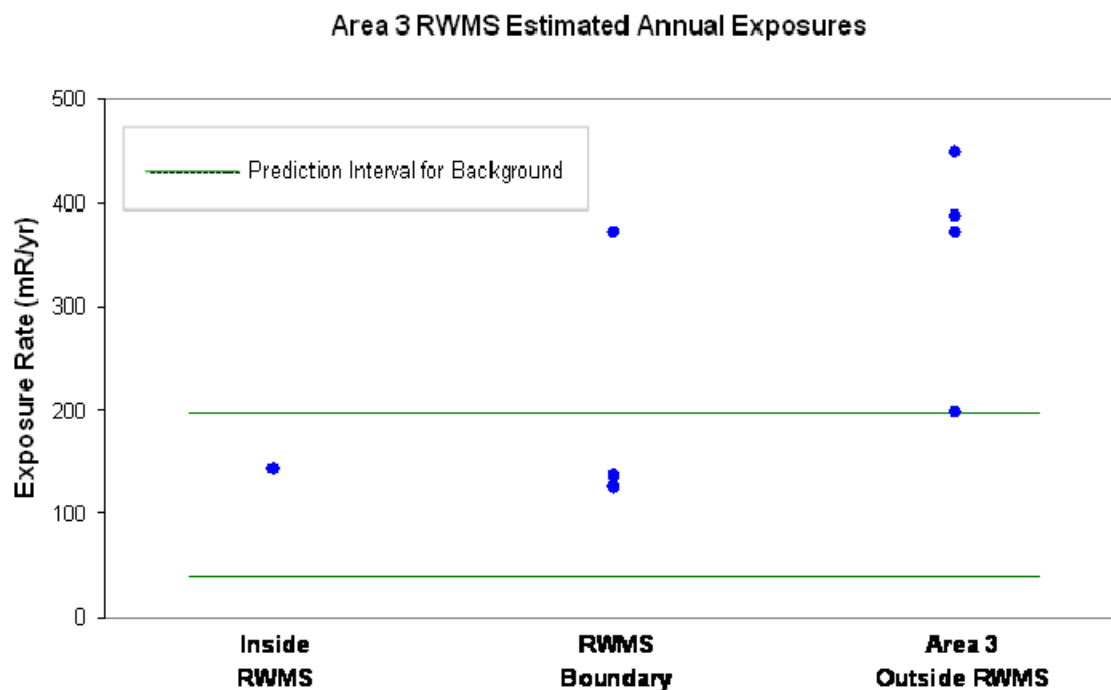


Figure 4-1 Annual Exposure Rates at the Area 3 RWMS during 2007

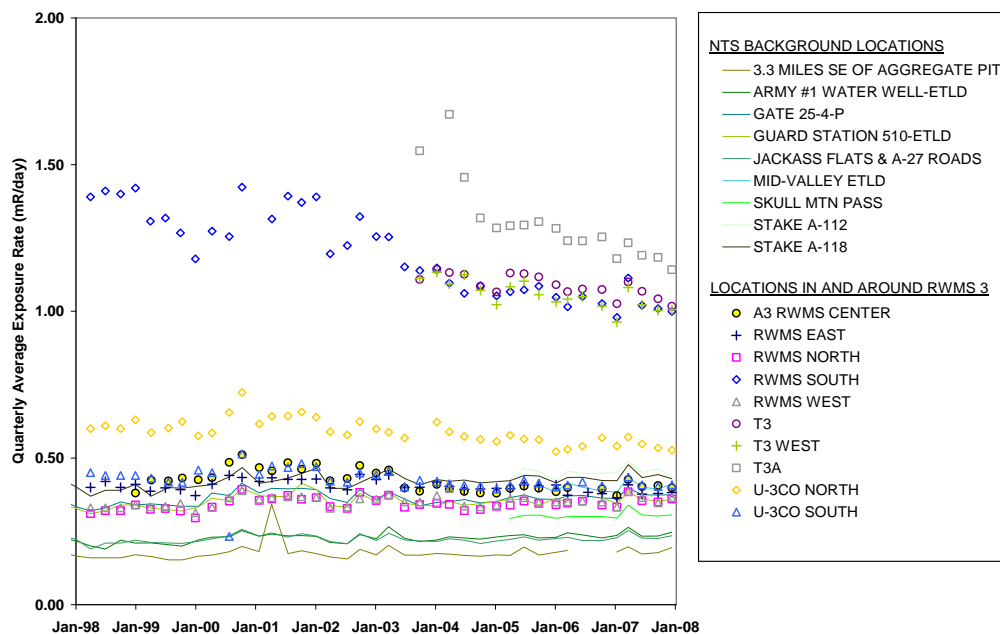


Figure 4-2 Quarterly Average Daily Exposure Rates at the Area 3 RWMS and NTS Background TLD Locations, 1998–2008

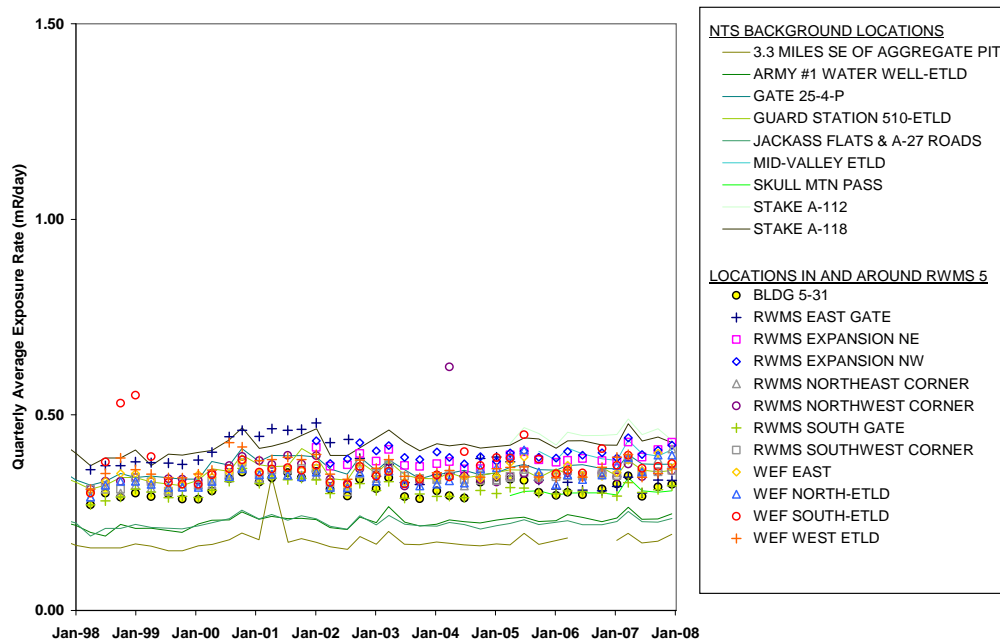


Figure 4-3 Quarterly Average Daily Exposure Rates at the Area 5 RWMS and NTS Background TLD Locations, 1998–2008

4.3 AIR MONITORING DATA

4.3.1 Tritium

Tritium is a highly mobile isotope of hydrogen that acts as a conservative tracer and is therefore an excellent performance indicator of volatile radionuclide migration from waste cells. Atmospheric moisture is continuously collected at the Area 3 and Area 5 RWMSs and analyzed for tritium. Approximately 11 cubic meters (m^3) (388 cubic feet [ft^3]) of air is drawn across a desiccant during each two-week sample period to collect atmospheric moisture. The moisture is distilled from the desiccant and the tritium activity is measured by liquid scintillation.

The tritium monitoring locations at the Area 3 RWMS are U-3bh N and U-3ah/at S (see Figure 3-1). The Area 5 RWMS monitoring locations are DoD, which is approximately 1.0 km (0.6 mi) north of the Area 5 RWMS, and Sugar Bunker, which is approximately 1.5 km (0.9 mi) south of the Area 5 RWMS (see Figure 3-3). These Area 5 monitoring locations are in the prevailing downwind directions from the RWMS and provide adequate environmental monitoring for the Area 5 RWMS.

During 2007, tritium concentrations at the Area 3 and Area 5 RWMSs showed normal levels of variability and were well below the DOE Derived Concentration Guide (DCG) for tritium (Figure 4-4). The DCG is the concentration of a radionuclide in air that if inhaled for one year would result in the DOE radiation limit of 100 mrem/yr committed effective dose equivalent to the public (DOE Order 5400.5).

Higher evapotranspiration (ET) during May through November 2007 result in higher tritium concentrations in air during this period (Figure 4-4). Beyond this normal variation, there were no emission events that could be attributed to RWMS operations during 2007. There was an event on December 19, 2005, at the Area 5 RWMS, when a Sealand[®] shipping container was being retrieved and, after being excavated, a puncture was discovered in this container. This allowed tritium to escape from the container (for more details see Section 3.1.4.5 of BN [2006a]). Although the puncture was quickly sealed upon discovery, tritium from the soil surrounding the container was likely the source of elevated tritium measured through June 2006 (Figure 4-5). This relatively minor tritium emission was easily detected by air monitoring.

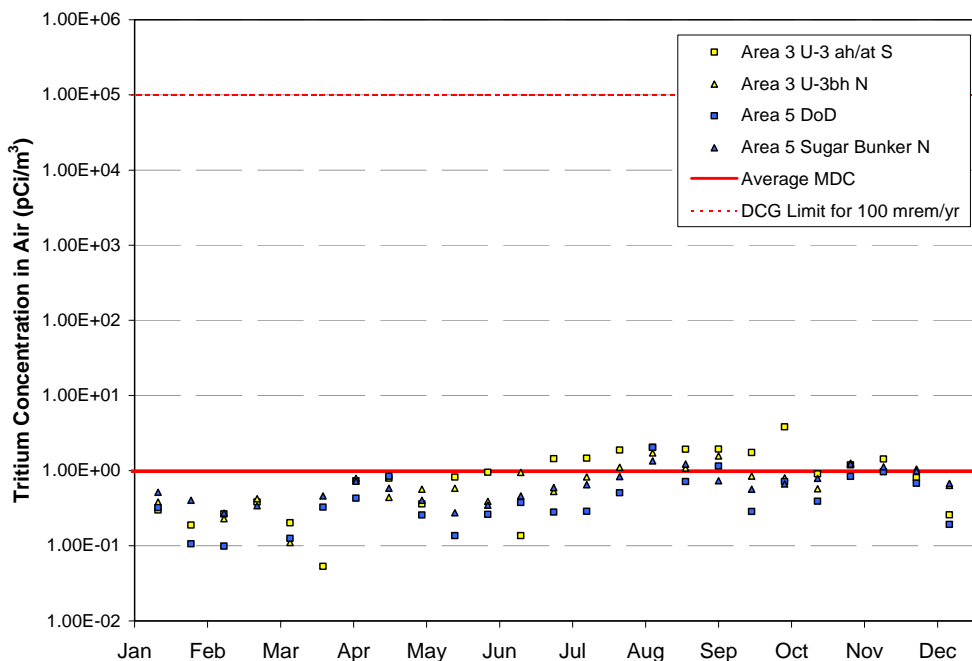


Figure 4-4 Tritium Concentrations in Air around the Area 3 and Area 5 RWMSs During 2007

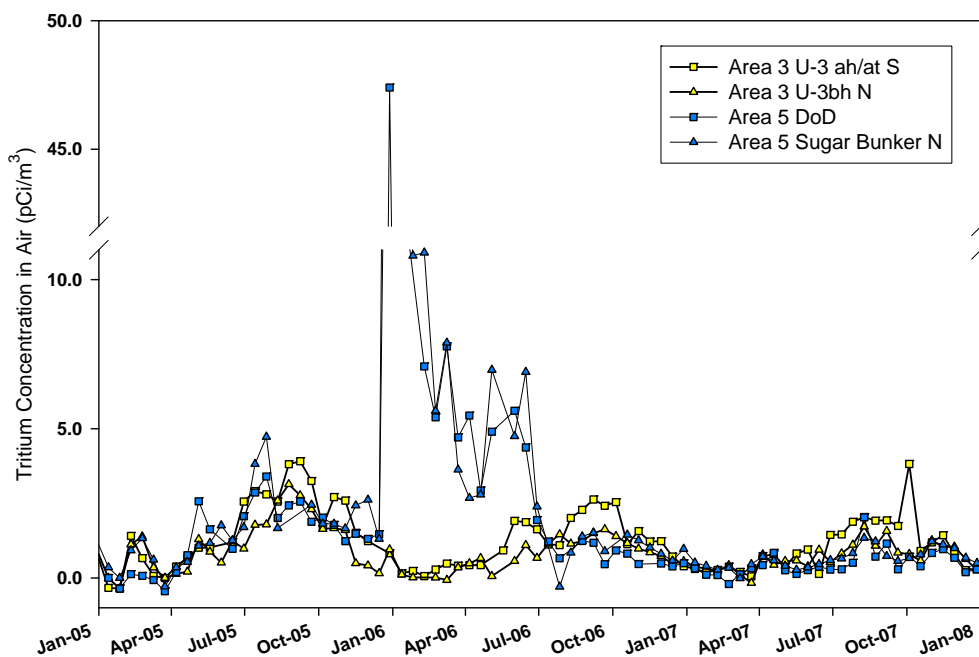


Figure 4-5 Tritium Concentrations in Air around the Area 3 and Area 5 RWMSs, 2005–2007

4.3.2 Particulates

Air particulate samples are collected weekly on glass-fiber filters near each RWMS and are screened for gross alpha and gross beta radioactivity to provide early detection of any change in environmental concentrations of airborne radioactivity. Monthly composites of the filters from each sampling location are analyzed by gamma spectroscopy for gamma-emitting radioactivity and by radiochemical analyses for americium and plutonium.

The four air particulate monitoring locations at the Area 3 RWMS are U-3bh N, U-3bh S, U-3ah/at N and U-3ah/at S (see Figure 3-1). The two air particulate monitoring locations at the Area 5 RWMS are DoD and Sugar Bunker (Figure 3-3).

The 2007 gamma spectroscopy results were below the sample-specific minimum detectable concentration (MDC) except for one ^{137}Cs measurement of 0.000590 ± 0.000335 picocuries per cubic meter (pCi/m^3) from the U-3bh N sampling location ($\text{MDC} = 0.000524 \text{ pCi}/\text{m}^3$). All mean values for ^{137}Cs were near zero and there were slightly more negative mean values than positive mean values.

The 2007 alpha spectroscopy results for americium and plutonium were above the MDCs in 8 to 50 percent of the samples (Figure 4-6, Figure 4-7, and Figure 4-8). The americium and plutonium concentrations at the Area 3 RWMS were slightly higher than at the Area 5 RWMS. There is no indication that RWMS operations contributed americium or plutonium activity above normal variability observed at all locations. All measured concentrations of americium and plutonium were below the DCG for each radionuclide.

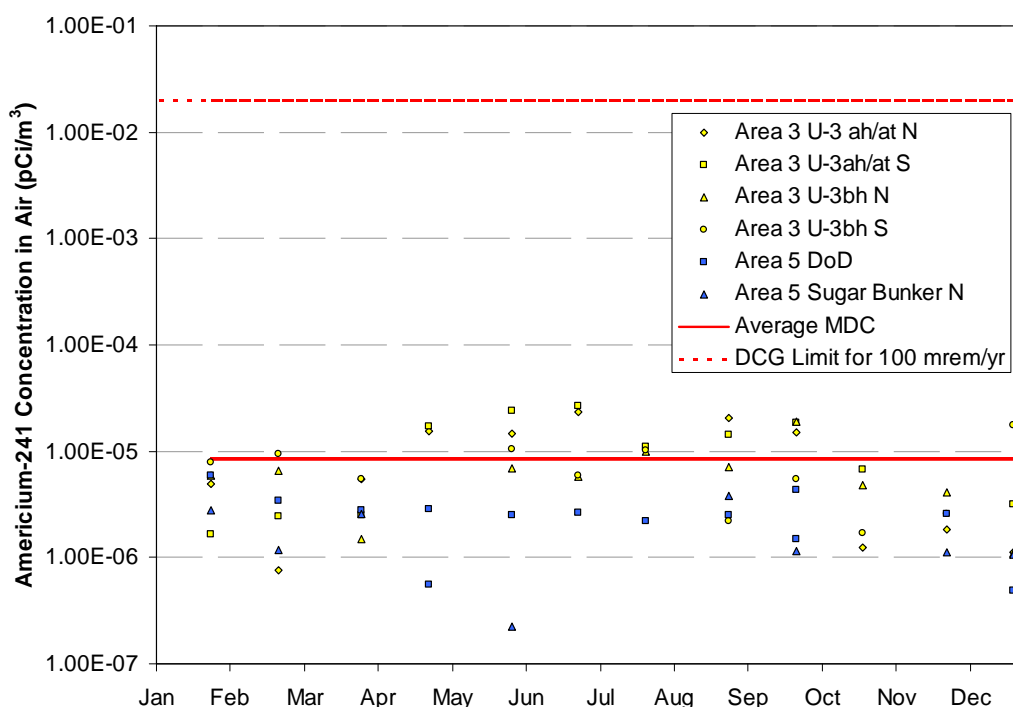


Figure 4-6 ^{241}Am Concentrations in Air around the Area 3 and Area 5 RWMSs During 2007

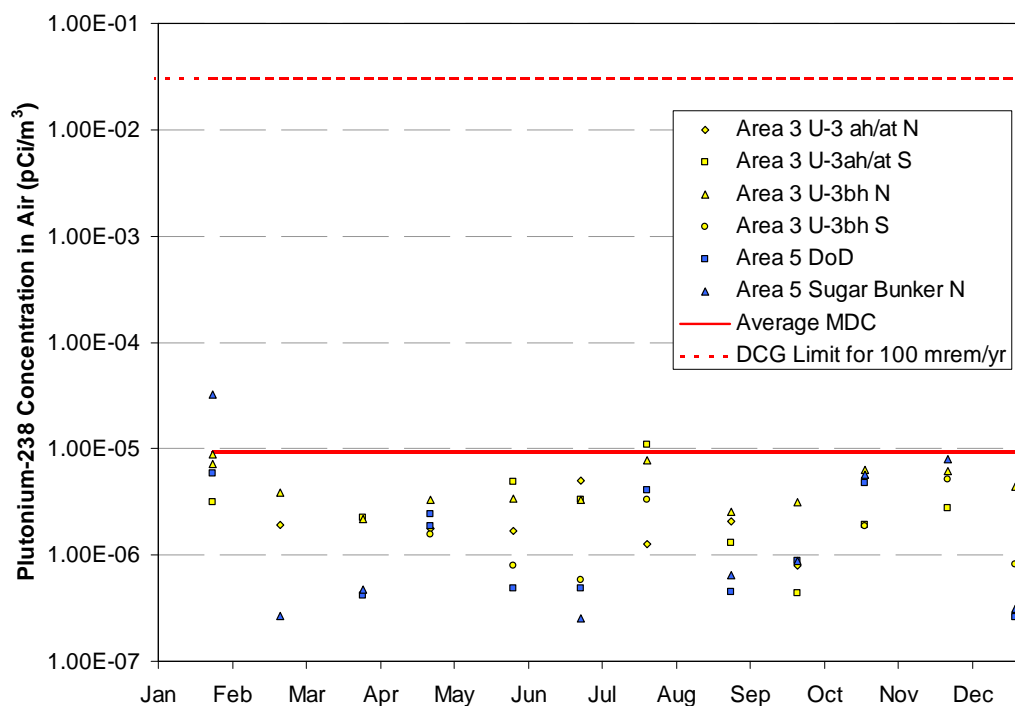


Figure 4-7 ^{238}Pu Concentrations in Air around the Area 3 and Area 5 RWMSs During 2007

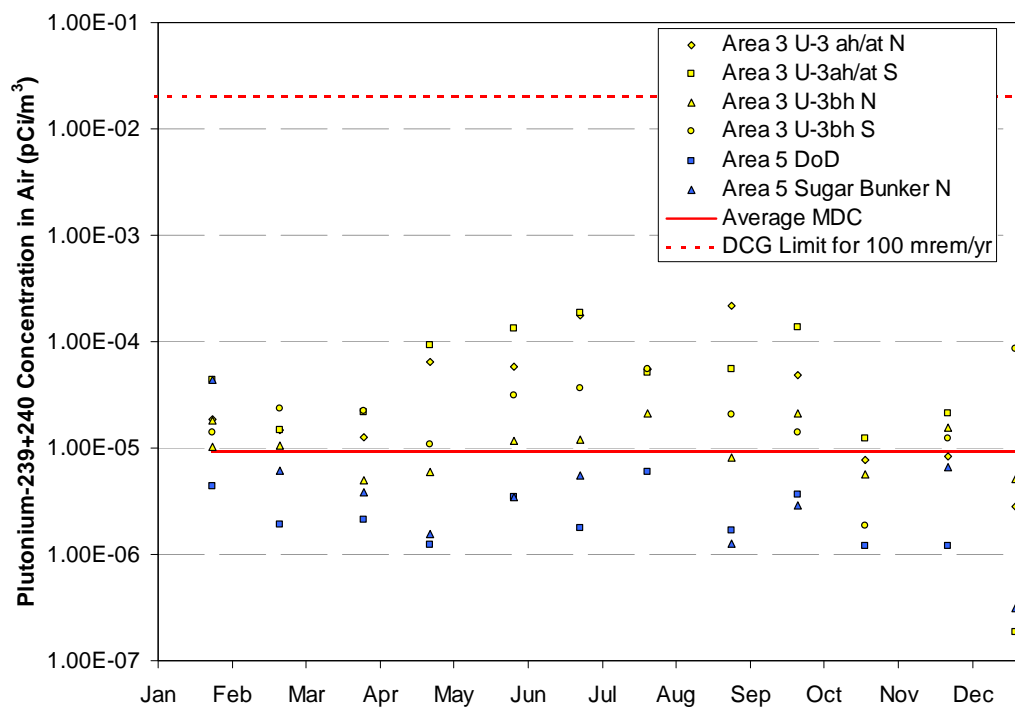


Figure 4-8 $^{239+240}\text{Pu}$ Concentrations in Air around the Area 3 and Area 5 RWMSs During 2007

4.3.3 Radon

The performance objective (DOE Order 435.1) and regulatory limit (Title 40 CFR 61, Subpart Q) for radon emissions from DOE facilities is 20 picocuries per square meter per second. Radon flux measurements were made December 10–17, 2007, on the U-3ax/bl cover in Area 3 and on the P01U (Pit 1) cover in Area 5. These pits were selected because they contain radon and thorium-bearing waste. Radon flux was also measured at two undisturbed control sites outside both the Area 3 and Area 5 RWMSs. Figure 4-9 shows the measurement locations in Area 3 and Figure 4-10 shows the measurement locations in Area 5. Radon flux measurements were performed using radon flux domes (manufactured by Rad Elec, Inc.) placed on the ground surface. Electrets inserted in the domes are electrically discharged by ionization of air from radon. The amount of discharge is correlated to the radon flux from the ground.

Radon flux results for 2000 to 2007 are summarized in Figure 4-11. All 2007 radon flux measurements were at least 7 times lower than the regulatory limit. Radon flux results for the Area 5 control location at the Weighing Lysimeter Facility were slightly higher than the Pit 1 results. At the Area 3 RWMS, measurements were concentrated on the west side of the U-3ax/bl cover in an attempt to repeat measurements made during December 2006. The 2006 results showed slightly higher radon flux on the cover than was observed in previous years. Results from 2007 were also slightly elevated but not to the extent observed during 2006 (Figure 4-11).

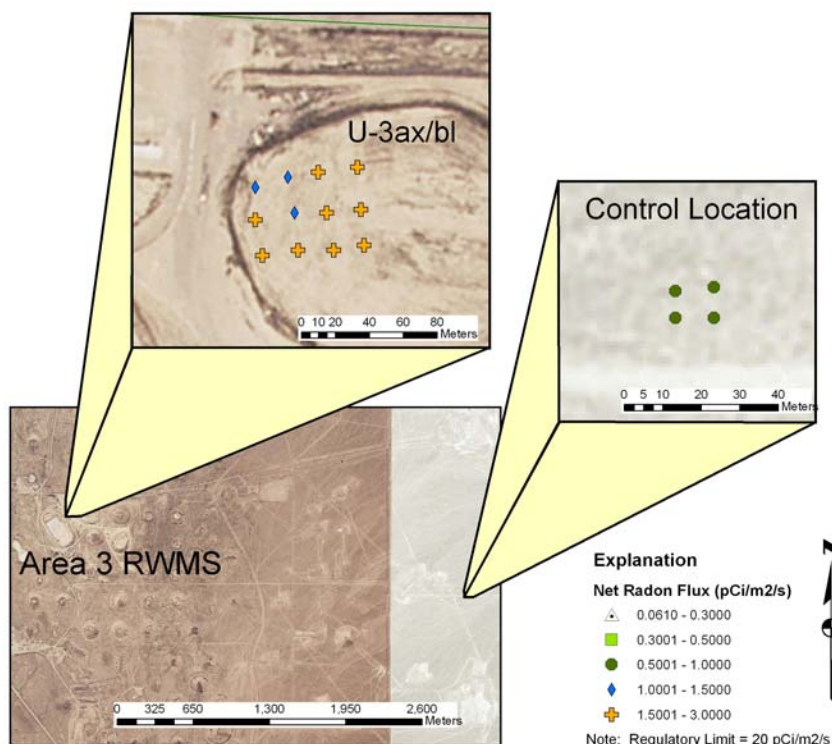


Figure 4-9 Radon Flux Measurements in Area 3 During 2007

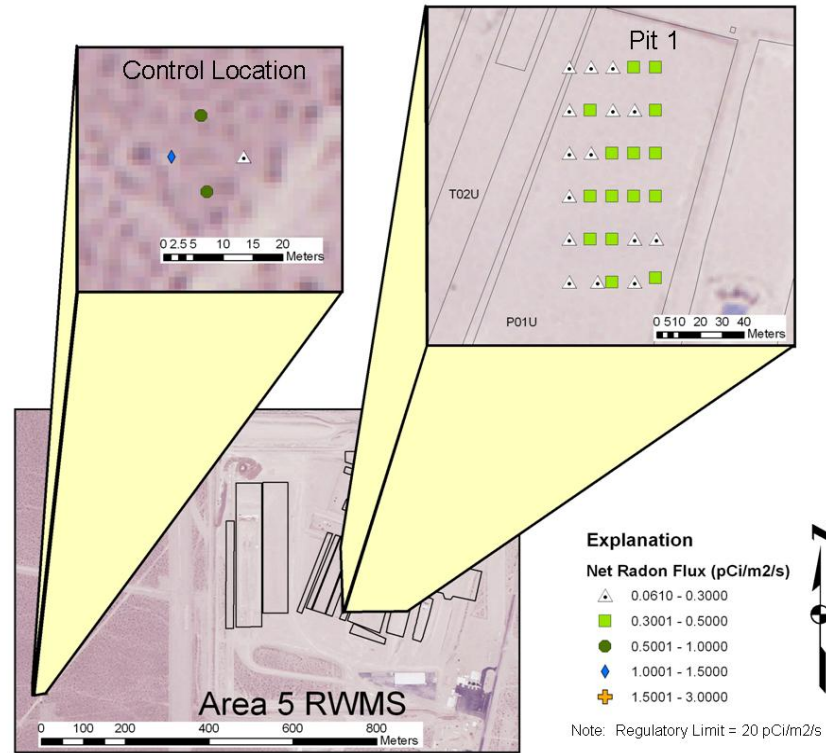


Figure 4-10 Radon Flux Measurements in Area 5 During 2007

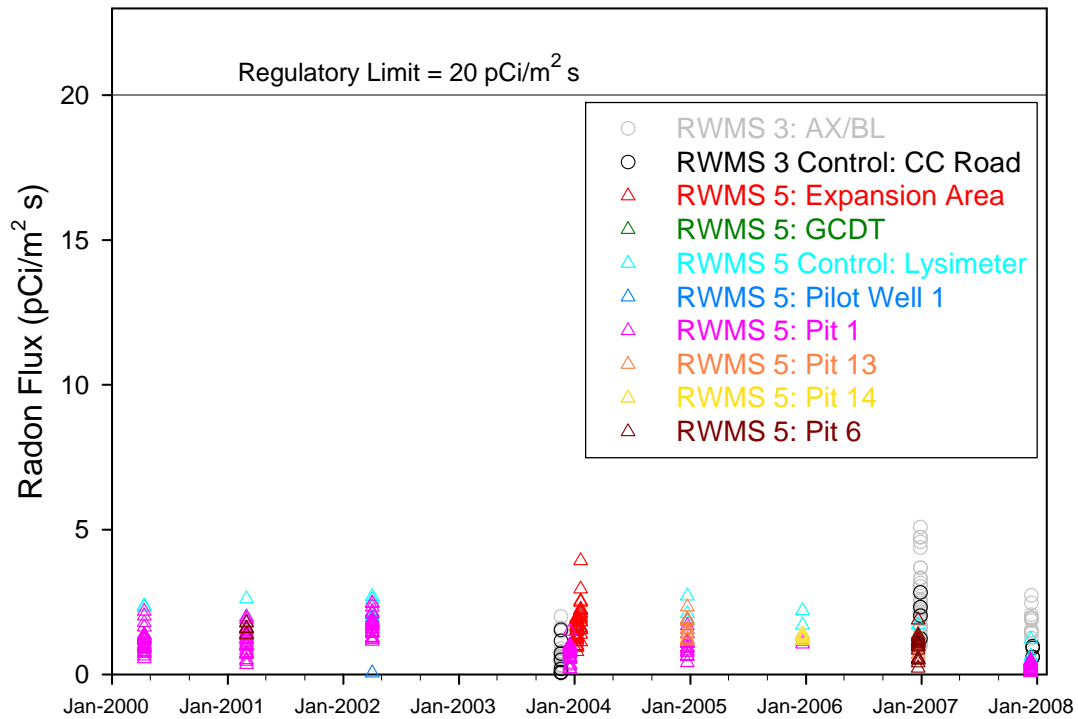


Figure 4-11 Radon Flux Measurements from 2000 to 2007

4.4 GROUNDWATER MONITORING DATA

Three wells (UE5PW 1, UE5PW 2, and UE5PW 3) were drilled around the perimeter of the Area 5 RWMS in 1993 (see Figure 3-3). The groundwater at these wells is sampled twice a year. SC, pH, TOC, TOX, and tritium are measured as indicators of contamination migration. General water chemistry parameters are also measured. To date, all analytical data from groundwater sampling events from the wells indicate that the groundwater in the uppermost aquifer is unaffected by activities at the Area 5 RWMS. Detailed information and data on the groundwater monitoring program at the Area 5 RWMS are presented in the Nevada Test Site 2007 Data Report: Groundwater Monitoring Program, Area 5 Radioactive Waste Management Site (NSTec, 2008).

Groundwater elevation measurements are taken quarterly using an electronic tape. All groundwater elevation data from manual measurements taken since the wells were drilled in 1993 are shown in Figure 4-12. These data indicate that the water table beneath the Area 5 RWMS is flat, with little or no groundwater flow.

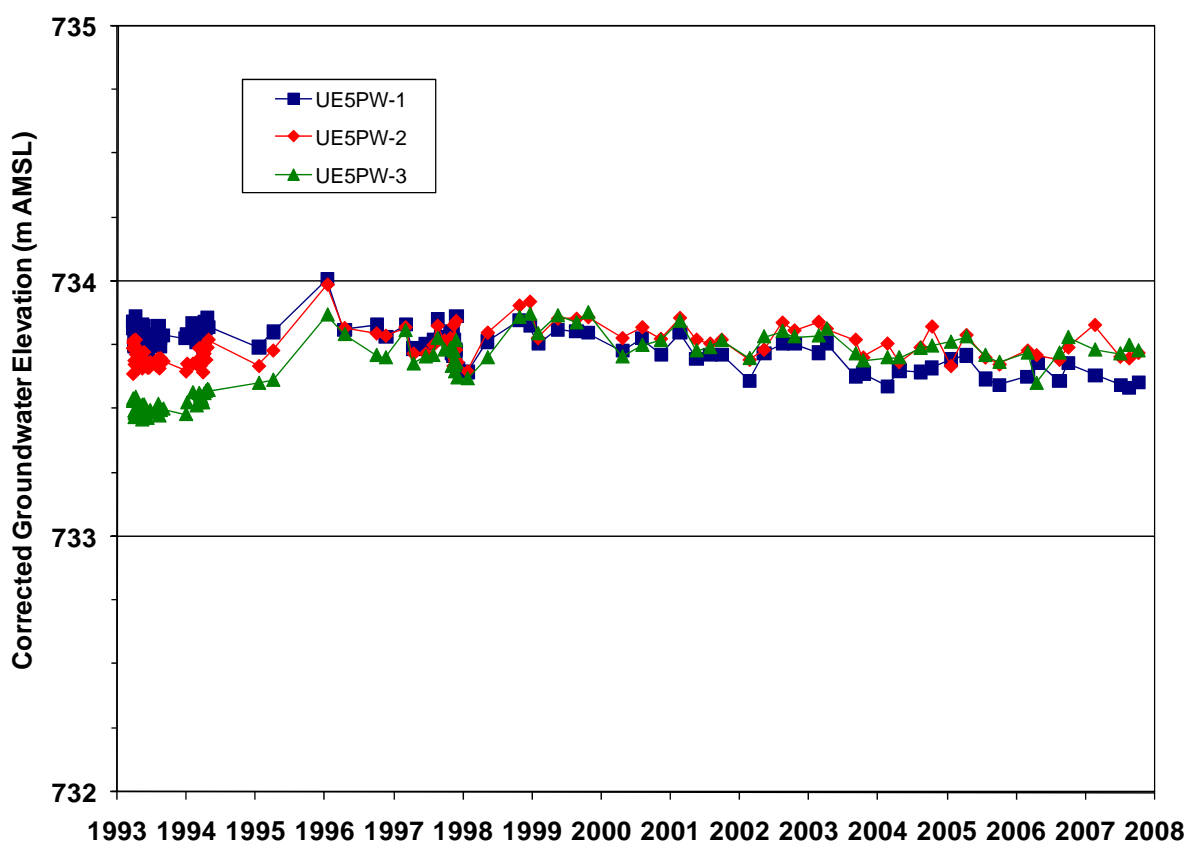


Figure 4-12 Groundwater elevation at the Three Area 5 RWMS Pilot Wells

4.5 METEOROLOGY MONITORING DATA

Meteorology monitoring data collected in 2007 include precipitation, air temperature, humidity, wind speed and direction, barometric pressure, and incoming solar radiation. These are basic meteorological parameters required to quantify the exchange of water and heat between the soil and the atmosphere. These data were collected from two meteorology stations, one located approximately 30 m (100 ft) northwest of the Area 3 RWMS, and one near the Area 5 RWMS about 100 m (328 ft) north from Well UE5PW 1 (see Figure 3-1 and Figure 3-2).

4.5.1 Air Temperature

Air temperatures at the Area 3 RWMS are slightly cooler than air temperatures at the Area 5 RWMS. The 2007 average recorded temperatures at 3 m (10 ft) are 14.5°C (58.1°F) at the Area 3 RWMS, and 16.4°C (61.5°F) at the Area 5 RWMS. The 2007 maximum and minimum temperatures at 3 m (10 ft) are 41.5°C (106.7°F) and -15.1°C (4.8°F) at the Area 3 RWMS and 43.9°C (111.0°F) and -14.7°C (5.5°F) at the Area 5 RWMS (Figure 4-13).

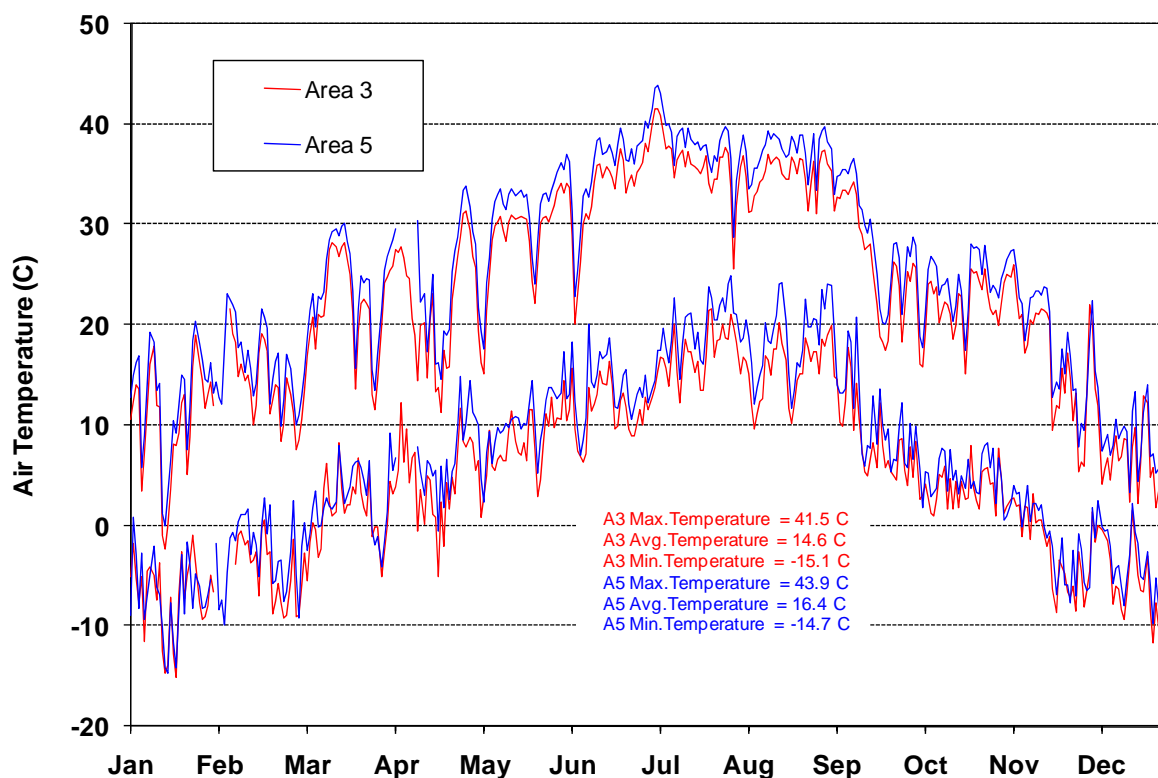


Figure 4-13 Daily Maximum and Minimum Air Temperature at the Area 5 and Area 3 RWMSs

4.5.2 Relative Humidity

Measured relative humidity at the Area 3 RWMS and the Area 5 RWMS are similar. The daily average relative humidity during 2007 at these two sites is approximately 30 percent (Figure 4-14). Measured relative humidity ranged from 2 percent to 100 percent.

4.5.3 Barometric Pressure

Average daily barometric pressure measured at the Area 3 RWMS and the Area 5 RWMS show very similar patterns (Figure 4-15). The difference in barometric pressure readings between the two locations is caused by the 261 m (856 ft) difference in elevation.

4.5.4 Wind Speed and Direction

The average wind speed is slightly higher at the Area 3 RWMS than at the Area 5 RWMS. During 2007, the average wind speed at the Area 3 RWMS was 3.3 meters per second (m/s) (7.4 miles per hour [mph]) and the maximum gust was 20.0 m/s (44.7 mph). During 2007, the average wind speed at the Area 5 RWMS was 2.7 m/s (5.8 mph) and the maximum gust was 20.9 m/s (46.8 mph). Daily maximum and average wind speeds are in Figure 4-16 and Figure 4-17.

Wind rose diagrams illustrate wind direction and wind speed distribution in each direction using hourly wind data measured at a height of 3 m AGL. Generally, more wind comes from the north and higher wind speeds come from the south. Wind roses from the Area 3 and Area 5 RWMSs are presented in Figure 4-18 and Figure 4-19, respectively. The one-year wind roses presented here are very similar to the multiple-year wind roses.

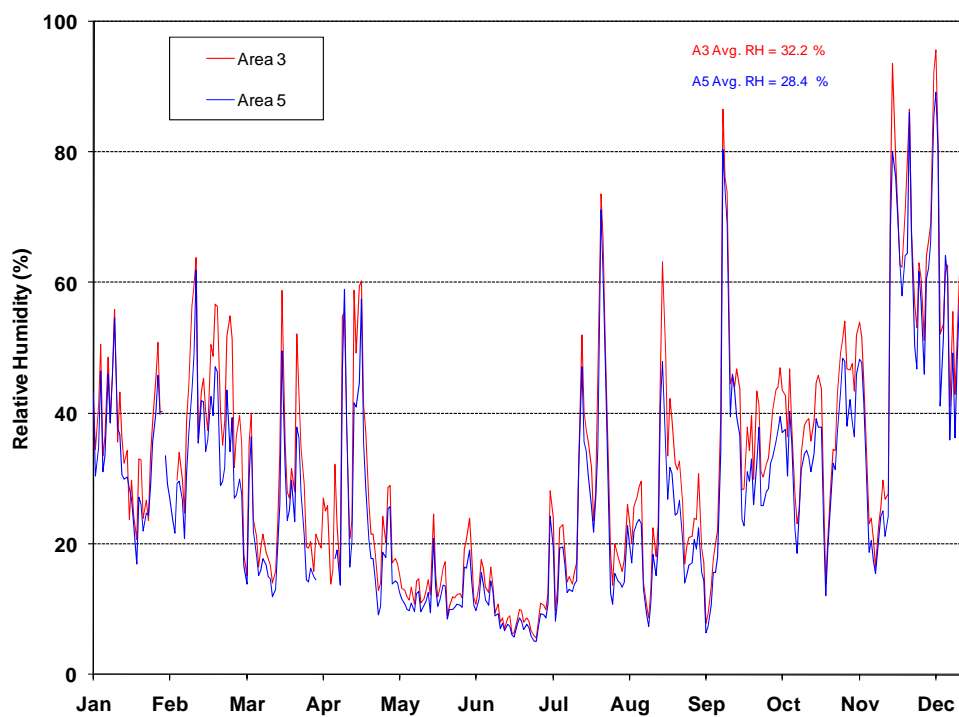


Figure 4-14 Daily Average Humidity at the Area 3 and Area 5 RWMSs

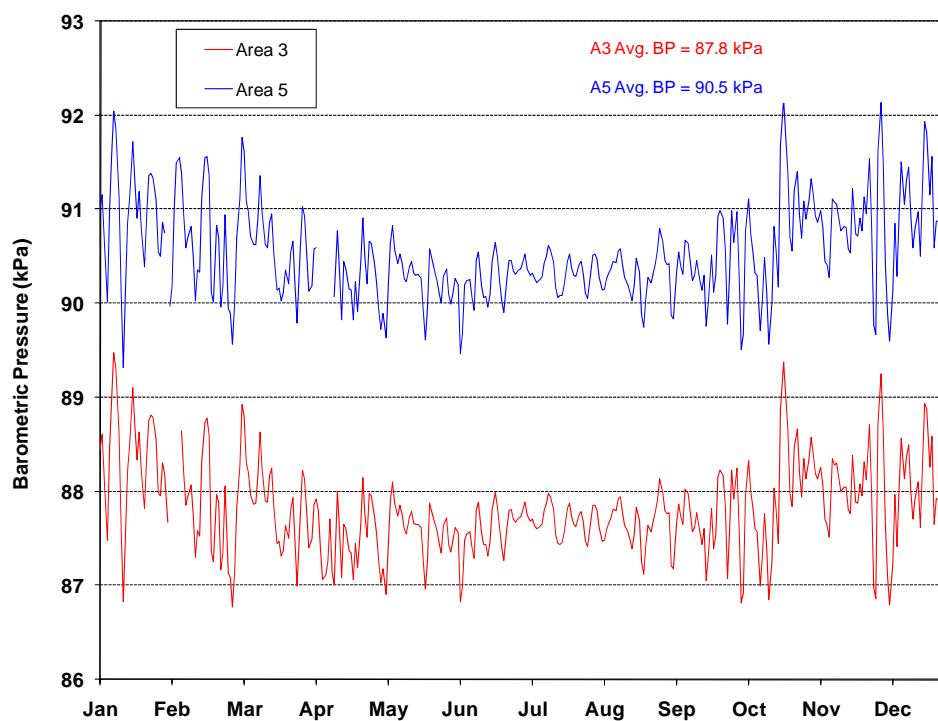


Figure 4-15 Daily Average Barometric Pressure at the Area 3 and Area 5 RWMSs

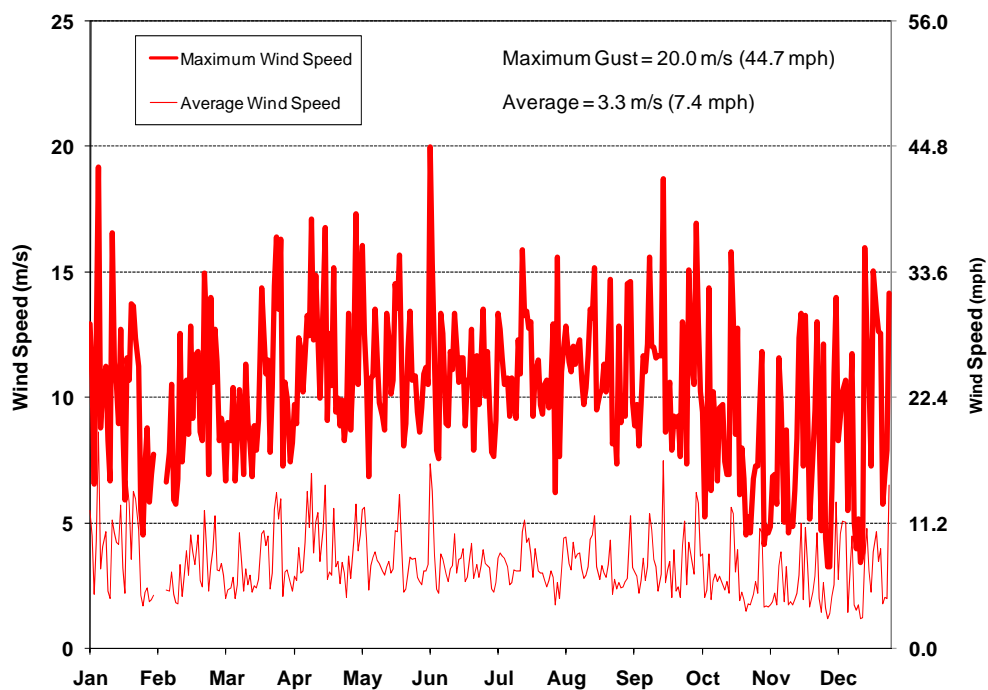


Figure 4-16 Daily 3 m Wind Speed at the Area 3 RWMS

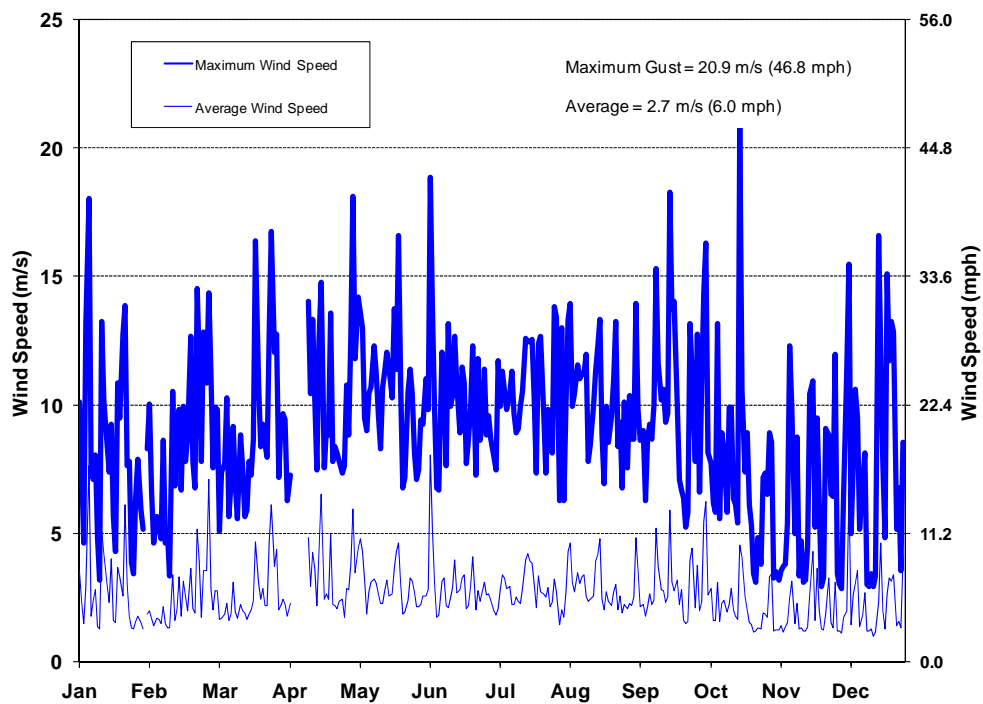


Figure 4-17 Daily 3 m Wind Speed at the Area 5 RWMS

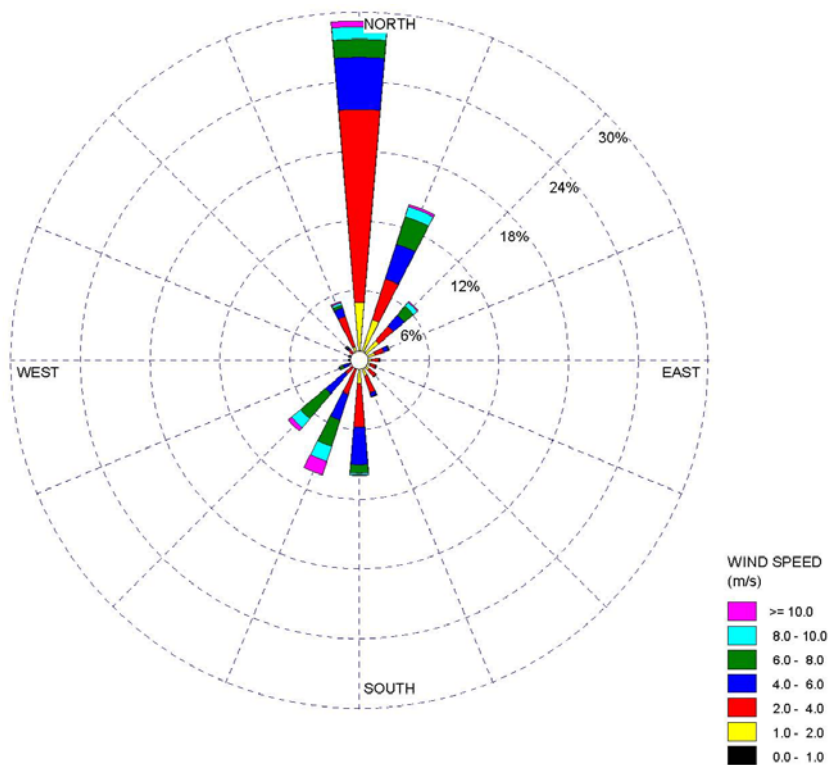


Figure 4-18 Wind Rose Diagram for the Area 3 RWMS

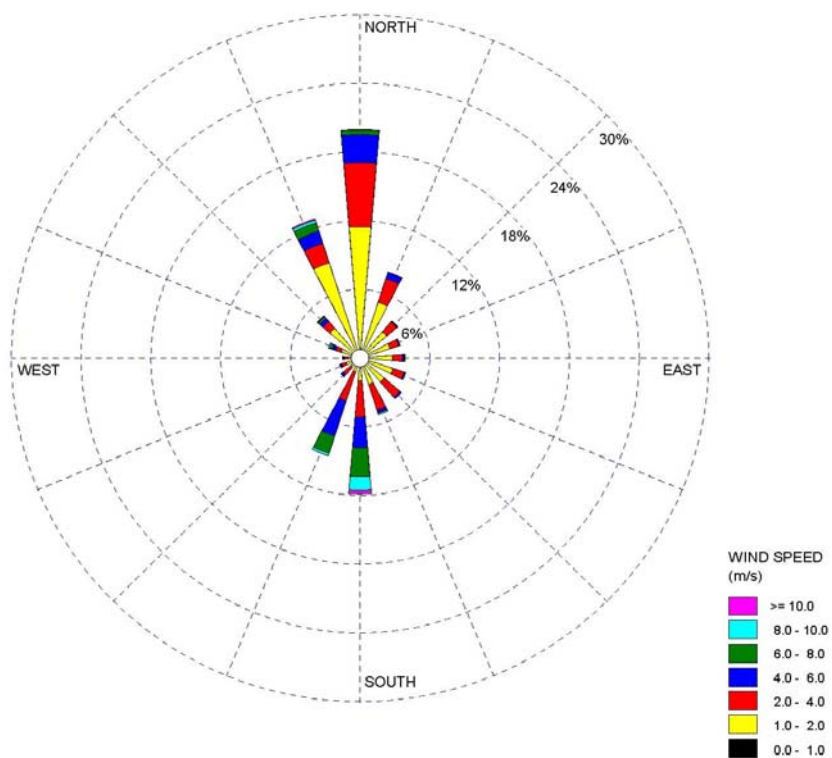


Figure 4-19 Wind Rose Diagram for the Area 5 RWMS

4.5.5 Precipitation

Rainfall at the Area 3 RWMS in 2007 was slightly below average, totaling 136.8 mm (5.39 in.). The average annual precipitation measured at the Area 3 RWMS for 1996 to 2007 was 158.1 mm (6.22 in.). The maximum daily rainfall at the Area 3 RWMS during 2007 was 42.5 mm (1.67 in.) on September 21, 2007. Precipitation was measured on 27 days, but 66.5 mm (2.62 in.) or 47.9 percent of the total 2007 precipitation occurred on September 21 and September 22, 2007.

Rainfall at the Area 5 RWMS in 2007 was also slightly below average, totaling 123.8 mm (4.87 in.). The average annual precipitation measured at the Area 5 RWMS for 1995 to 2007 was 130.7 mm (5.15 in.). The maximum daily rainfall at the Area 5 RWMS during 2007 was 38.8 mm (1.53 in.) on September 21, 2007. Precipitation was measured on 26 days, but 58.1 mm (2.29 in.) or 46.9 percent of the total 2007 precipitation occurred on September 21 and September 22, 2007. Figure 4-20 and Figure 4-21 depict the 2007 daily total precipitation at the Area 3 and Area 5 RWMSs.

Historical precipitation data recorded at BJY (located about 3 km [2 mi] northwest of the Area 3 RWMS) and at the Area 3 RWMS are in Figure 4-22. The BJY station is a Meteorological Data Acquisition (MEDA) station operated by ARL/SORD. The 47-year average annual precipitation at BJY from 1961 to 2007 is 163.7 mm (6.44 in.). Historical precipitation data recorded at the Well 5B station (located about 5.5 km [3.4 mi] south of the Area 5 RWMS) and the Area 5 RWMS are provided in Figure 4-23. The Well 5B station is also an ARL/SORD MEDA station. The 45-year average annual precipitation at Well 5B from 1963 to 2007 is 124.9 mm (4.92 in.).

4.5.6 Reference Evapotranspiration

The calculated 2007 ET_{ref} at the Area 3 RWMS is 1,618 mm (63.7 in.) and at the Area 5 RWMS is 1,594 mm (62.8 in.). ET_{ref} is the rate that readily available soil water is vaporized from a uniform surface of dense, actively growing vegetation. Crop coefficients are used to convert ET_{ref} to potential evapotranspiration rates (Allen et al., 2005). ET_{ref} is calculated using a modified version of the radiation-based equation of Doorenbos and Pruitt (1977). The equation calculates ET_{ref} from hourly measurements of solar radiation, air temperature, relative humidity, wind speed, and barometric pressure. This method provides results similar to the Penman Equation that was previously used for the data reports through 2001 (Campbell, 1977). The Doorenbos and Pruitt equation reduces data input requirements because no net radiation data are used. The ratio of ET_{ref} to precipitation in 2007 at the Area 3 RWMS is 11.8, and the ratio ET_{ref} to precipitation in 2007 at the Area 5 RWMS is 12.9.

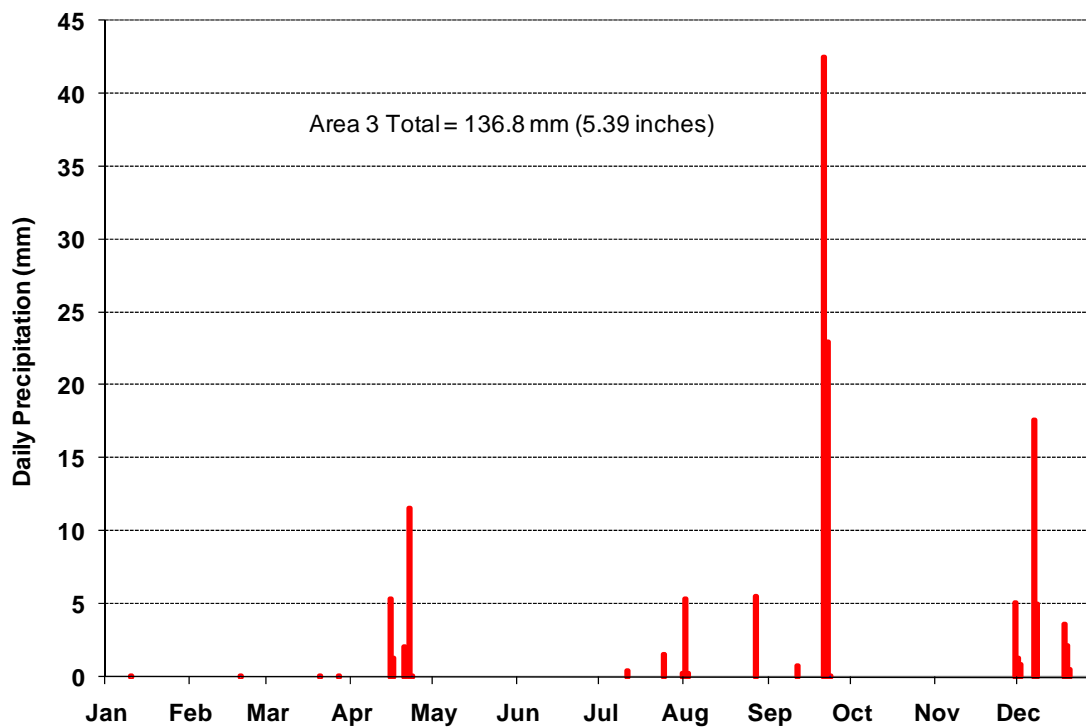


Figure 4-20 Daily Precipitation at the Area 3 RWMS

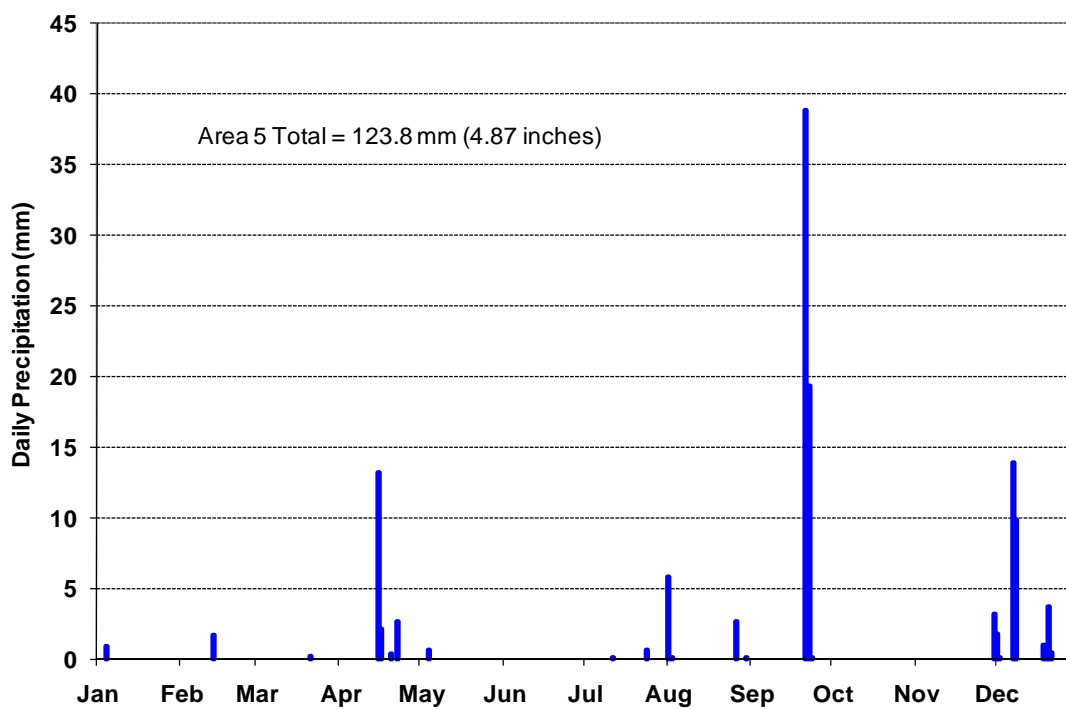


Figure 4-21 Daily Precipitation at the Area 5 RWMS

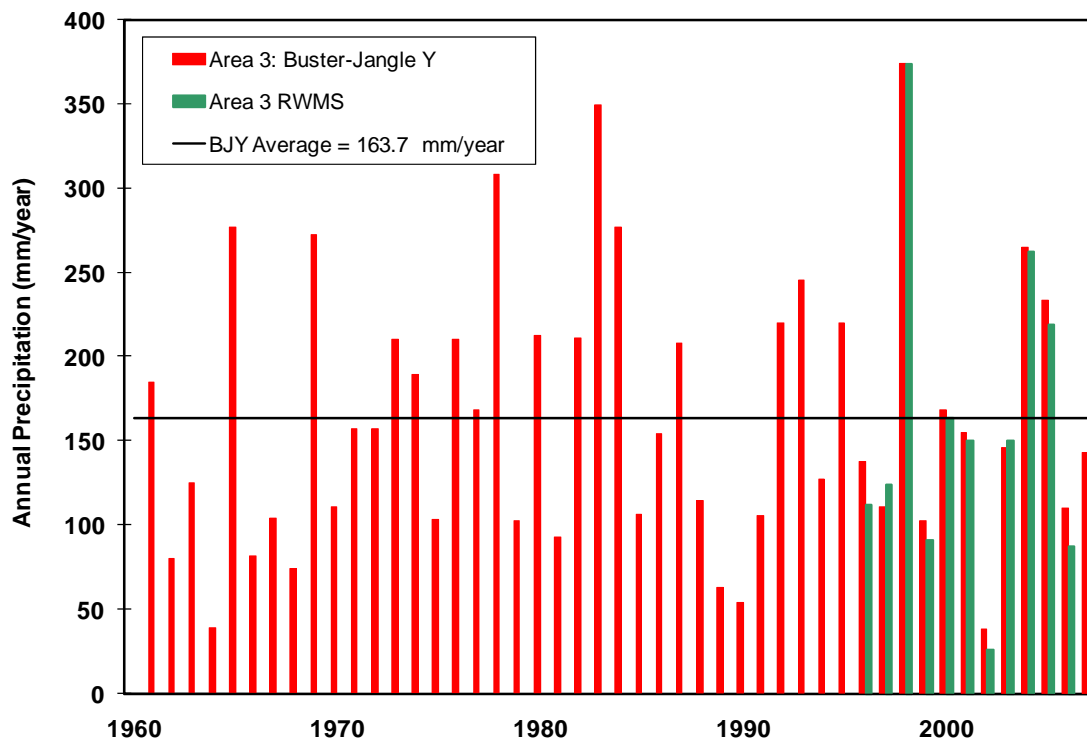


Figure 4-22 Historical Precipitation Record for Buster-Jangle Y and the Area 3 RWMS

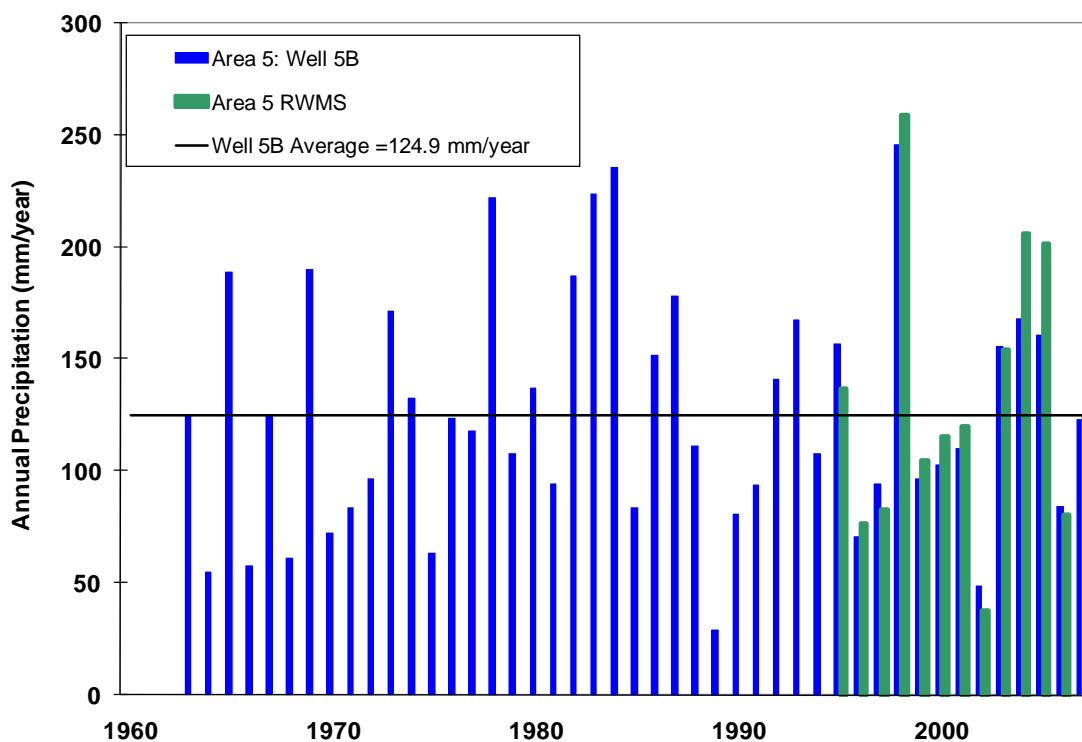


Figure 4-23 Historical Precipitation Record for Well 5B and the Area 5 RWMS

4.6 VADOSE ZONE MONITORING DATA

4.6.1 Monitoring Strategy

Vadose zone monitoring is conducted at the Area 3 and Area 5 RWMSs to demonstrate compliance with DOE Orders 5400.1 and 435.1 and confirm the assumptions made in the PA for each RWMS (e.g., hydrologic conceptual models, including soil water contents, upward and downward flux rates, and volatile radionuclide releases). The vadose zone monitoring is also performed to detect changing trends in performance, provide added assurance to PA conclusions regarding facility performance, evaluate the performance of the operational monolayer waste covers, and confirm the PA performance objective of protecting groundwater resources.

The design of the current vadose zone monitoring program at the RWMSs is based on an understanding of the vadose zone system acquired through extensive characterization studies (BN, 1998; 2005a; 2005b; Blout et al., 1995; Reynolds Electrical & Engineering Co., Inc., 1993a; 1993b; Shott et al., 1997; 1998; Tyler et al., 1996) and modeling studies (Levitt et al., 1999). The objectives of the vadose zone monitoring program are accomplished, in part, by measuring water balances at each RWMS. Water balance studies involve using meteorology data to calculate ET_{ref} values (the driving force of upward flow), directly measuring ET and bare-soil E at the RWMS lysimeter facilities, and measuring soil water content and soil water potential in waste cell covers and floors using automated waste cover monitoring systems. The vadose zone monitoring strategy also evaluates the subsurface migration of tritium by sampling soil gas for the presence of tritium at borehole GCD-05U located near the center of Area 5 RWMS (see Figure 3-2).

4.6.2 Soil Gas Tritium

Soil gas tritium monitoring is conducted via soil gas sampling at borehole GCD-05U. This 3.0 m (10 ft) diameter borehole has a large tritium inventory (~2.2 million curies (Ci) at time of disposal) buried from 20 to 37 m (65 to 120 ft) below ground surface. Two separate strings of nine soil gas sampling ports are buried in the borehole. The sampling ports are at depths of 3.0 m (10 ft), 6.1 m (20 ft), 9.1 m (30 ft), 12.2 m (40 ft), 15.2 m (50 ft), 19.8 m (65 ft), 25.9 m (85 ft), 33.5 m (110 ft), and 36.3 m (119 ft) below ground surface. Soil gas is pumped from the sampling ports to the surface at a low flow rate (2 cubic centimeters per minute). A cold trap removes water vapor from the air stream, and the tritium activity of the water is measured by liquid scintillation. Typically 25 liters of soil gas sample provides approximately 0.35 grams of water. Tritium sampling at borehole GCD-05U provides a direct measure of changes in tritium activity with depth due to degradation of waste containers, advection, and diffusion. Sampling started in 1990 and has continued at least annually through 2007.

Soil gas tritium was sampled from the nine GCD-05U sampling depths in July 2007. The 17-year trend in results indicates that upward migration of tritium through soil from the waste level is extremely slow. Tritium concentrations have remained constant and low from the surface down to 12.2 m (40 ft). Tritium concentrations at 15.2 m (50 ft) slowly increased through 1997 but then leveled off. The sample ports at depths of 19.8, 25.9, 33.5, and 36.3 m (65, 85, 110, and 119 ft) are adjacent to the tritium source. Tritium concentrations at these depths have increased since 1990. The highest measured soil gas tritium concentration of 363.9 microcuries per cubic meter ($\mu\text{Ci}/\text{m}^3$) indicates that most of the 2.2 million Ci originally buried at the site remains contained. Soil gas tritium concentrations with depth and time are illustrated in Figure 4-24 and Figure 4-25.

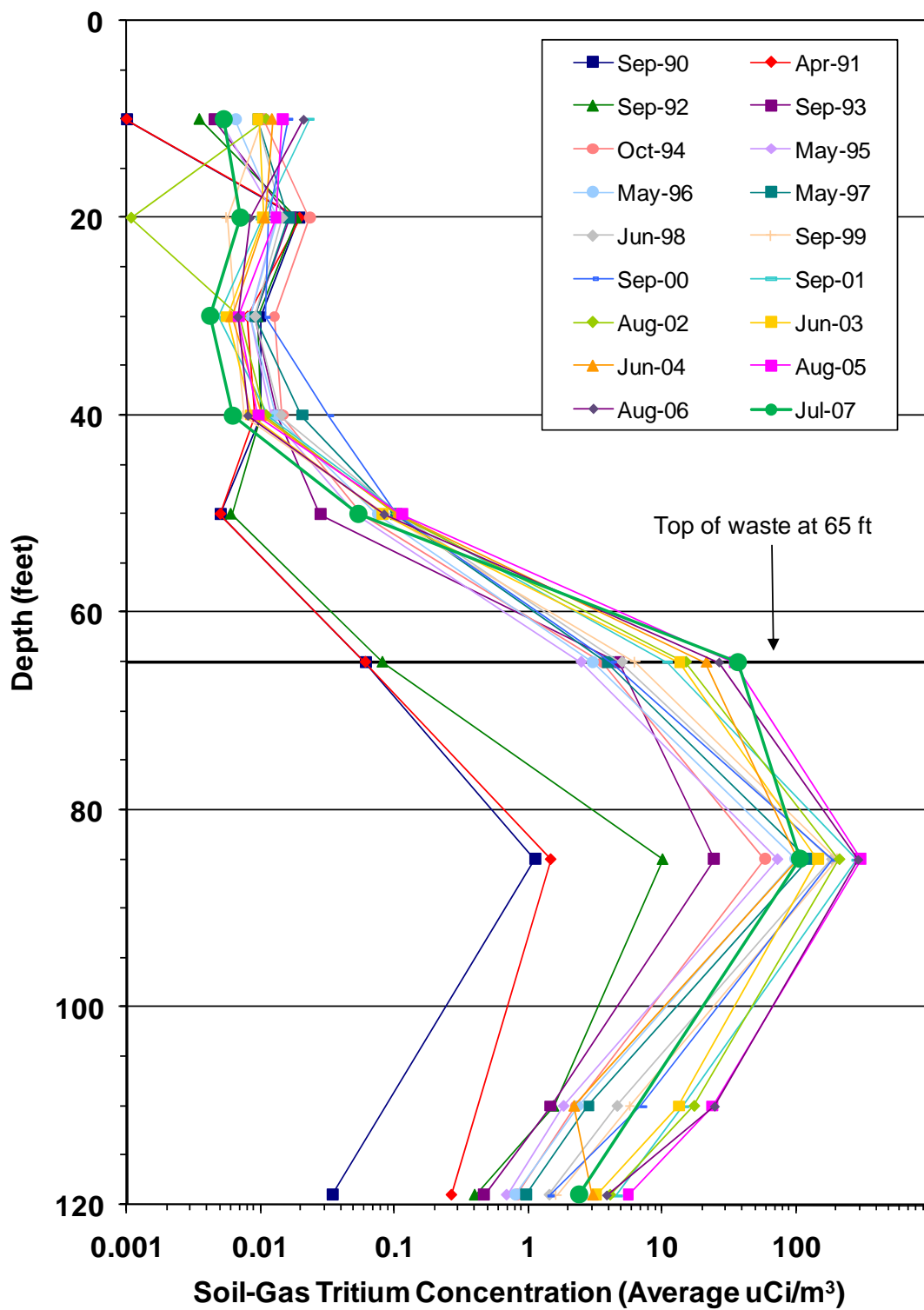


Figure 4-24 Soil-Gas Tritium Concentrations with Depth at GCD-05U

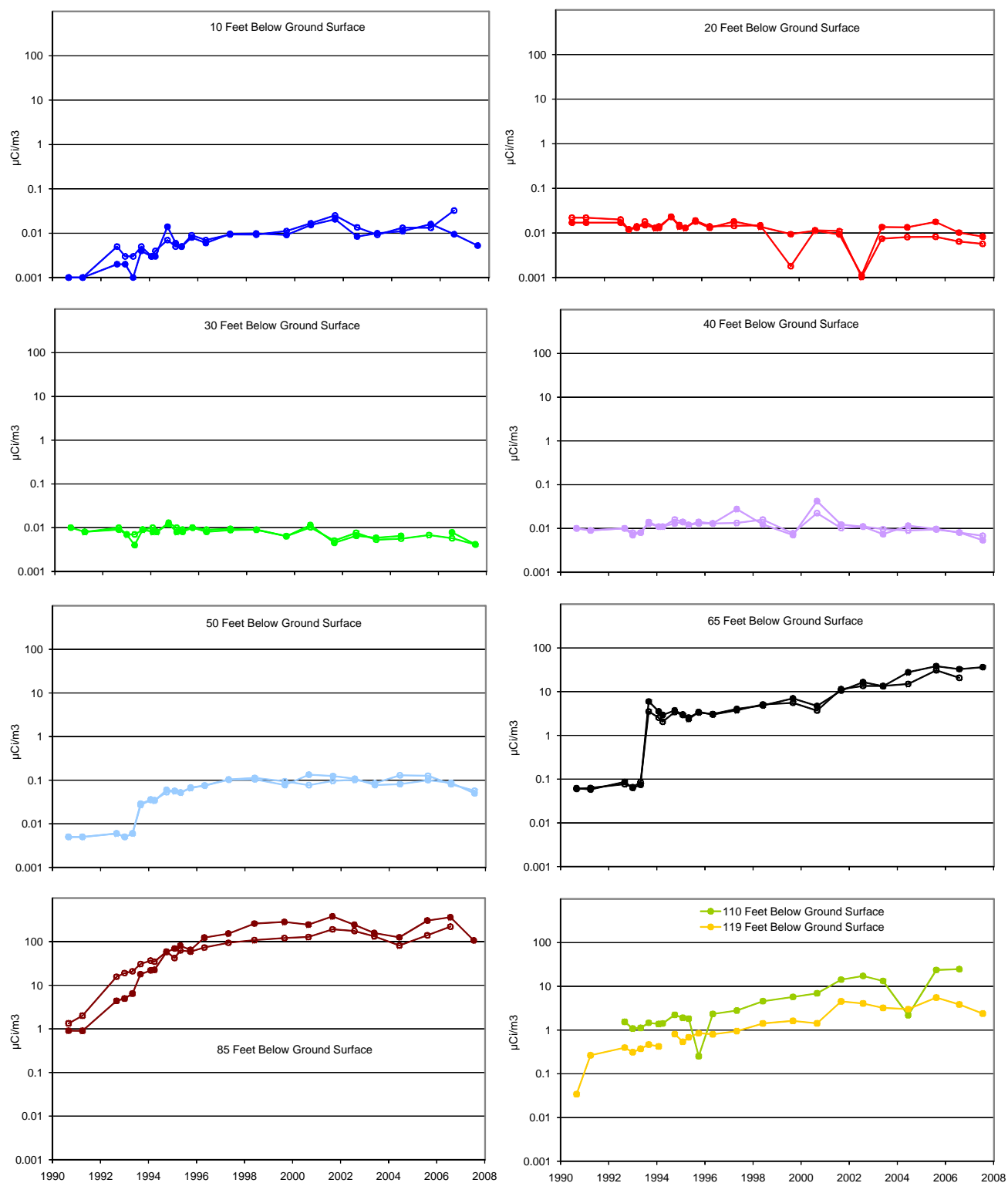


Figure 4-25 Soil-Gas Tritium Concentration for Each Depth at GCD-05U

4.6.3 Area 5 Weighing Lysimeter Facility

The Area 5 Weighing Lysimeter Facility consists of two precision weighing lysimeters located about 400 m (1,312 ft) southwest of the Area 5 RWMS (see Figure 3-3). Each lysimeter is a 2 m wide by 4 m long (6.6 wide by 13 ft long) by 2 m (6.6 ft) deep, open-top steel box filled with soil and mounted on a sensitive scale. Weight changes of each lysimeter are continuously monitored using an electronic load cell. Each load cell can measure approximately 0.1 mm (0.004 in.) of precipitation or ET. One lysimeter is vegetated with the native plant species Creosote bush (*Larrea tridentate*) and Anderson's wolfberry (*Lycium andersonii*) at the approximate density of the surrounding desert. The other lysimeter is kept bare to simulate the bare operational waste covers at the Area 5 RWMS. The load cells have provided an accurate data set of the surface water balance at the Area 5 RWMS since March 1994.

The weighing lysimeter data represent a simplified water balance: the change in soil water storage is equal to precipitation minus E (on bare lysimeters) or ET (on vegetated lysimeters). The water balance is simplified because no drainage can occur through the solid bottoms of the lysimeters and because a 2.5 cm (1 in.) lip around the edge of the lysimeters prevents run-on and runoff. Total soil water storage for the period of March 30, 1994, through December 31, 2007, is illustrated in Figure 4-26.

The vegetated lysimeter is considerably drier than the bare-soil lysimeter, despite the small number of plants on the vegetated lysimeter (about 15 percent plant cover). The average soil water storage depth in the vegetated lysimeter from January 1, 1996, to December 31, 2007, is 114 mm (4.5 in.). This is equivalent to an average volumetric water content of 5.72 percent. For the same period the average soil water storage depth in the bare lysimeter is 207 mm (8.1 in.), which is equivalent to an average volumetric water content of 10.35 percent. During 2007 the average soil water storage depth in the vegetated lysimeter is 110 mm (4.3 in.), and the average water storage depth in the bare lysimeter is 206 mm (8.1 in.).

Soil water storage decreases rapidly in the vegetated lysimeter following high rainfall periods due to ET. Typically, soil water decreases more slowly in the bare lysimeter due to E. Increases in soil water storage observed early in the data record in the vegetated lysimeter are a result of irrigation conducted to ensure survival of transplanted vegetation.

No water has ever accumulated at the bottom of the vegetated lysimeter. Heavy precipitation and low E rates during the period from October 2004 to February 2005, combined with initially high water contents, resulted in water accumulating at the bottom of the bare lysimeter starting in March 2005. This water continued to evaporate from the bare lysimeter during 2006 and 2007. Long-term numerical simulations (30 years) using a unit gradient bottom boundary were used to determine the amount of drainage that would have occurred if water could drain from the lysimeters. These simulations indicate an average of 1.0 cm/yr of water reaches the bottom of the bare lysimeter and that essentially no water reaches the bottom of the vegetated lysimeter (Desotell et al., 2006).

During 2007, E from the bare lysimeter was 86.7 mm (3.4 in.) and ET from the vegetated lysimeter was 88.8 mm (3.5 in.). Because both E and ET were less than the 118.7 mm (4.67 in.) of precipitation at the Weighing Lysimeter Facility, water storage increased in both lysimeters (Figure 4-27).

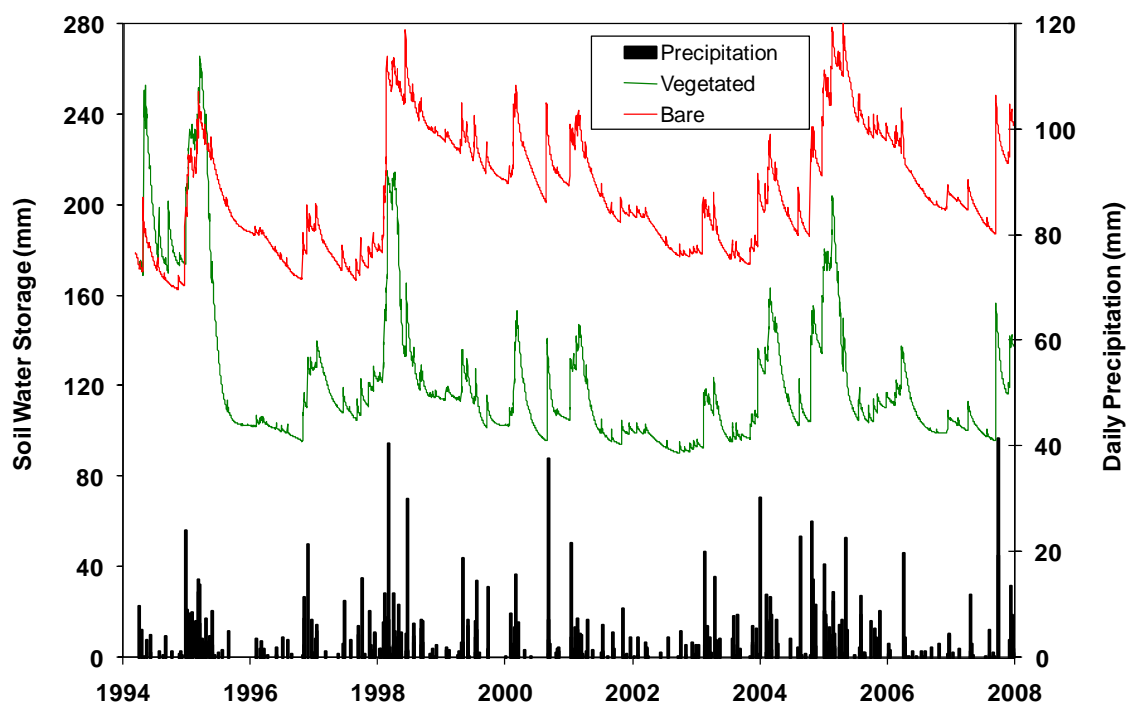


Figure 4-26 Weighing Lysimeter Data from March 1994 to December 2007

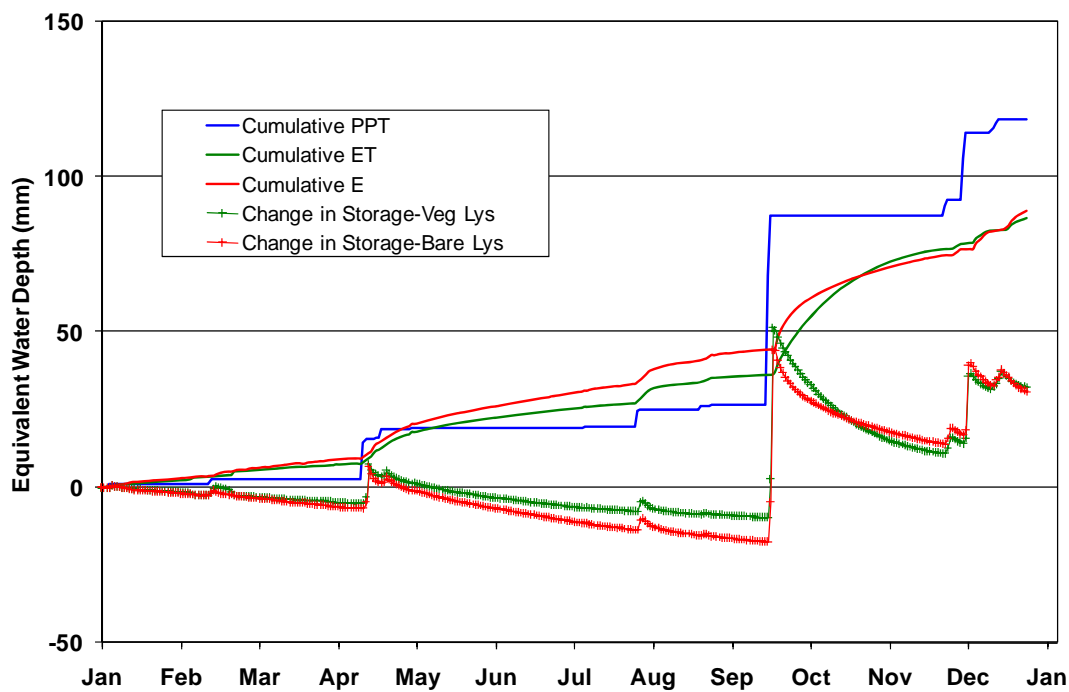


Figure 4-27 Cumulative Precipitation, ET, E, and Change in Storage for the Weighing Lysimeters in 2007

Precipitation exceeded both E and ET in April, July, September, and December. ET exceeded E in October and November 2007. It was dry from April 2006 to September 20, 2007, with only 52.3 mm (2.1 in.) precipitation during this period. This resulted in less water being available for plant growth and ET at the vegetated lysimeter. During this period, the wetter bare lysimeter provided more water near the surface for E. There were 60.1 mm (2.4 in.) of precipitation on September 20 and 21, 2007. The resulting plant growth and increase in available water caused ET to be greater than E in October and November 2007 (Figure 4-28).

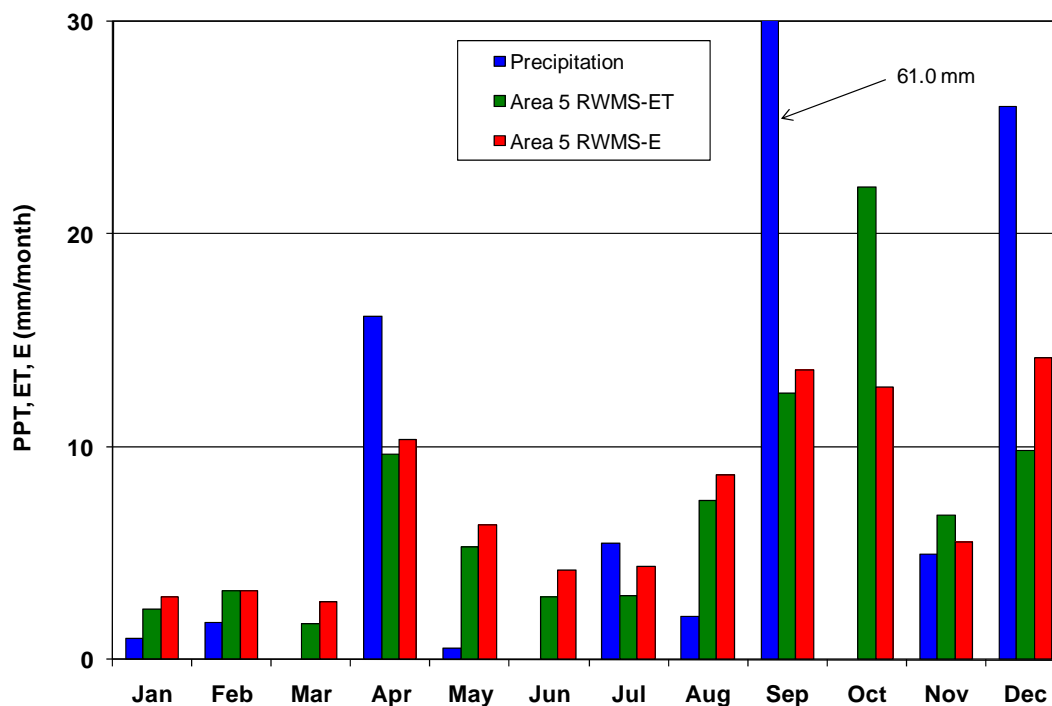


Figure 4-28 Monthly Precipitation, E, and ET Measured in the Weighing Lysimeters During 2007

4.6.4 Automated Waste Cover Monitoring System

In 1998, TDR probes were buried 1.2 m (4 ft) beneath the floor of open Pit 5 at the Area 5 RWMS. Approximately 4.4 m (14 ft) of waste and then approximately 2.3 m (8 ft) of operational cover were placed above these probes during disposal operations. The total depth of these probes is now approximately 7.9 m (26 ft). Measured volumetric water content in the floor of Pit 5 has remained constant at approximately 10 percent (Figure 4-29). The constant measured water content indicates that no moisture has percolated to 1.2 m (4 ft) below the waste.

In 1999, TDR probes were also installed in the operational cover of Pit 3 at two sites (north and south) at depths ranging from 10 to 180 cm (0.3 to 5.9 ft). Precipitation events, beginning in October 2004, infiltrated into the operational cover and percolated below the deepest probe at 180 cm (5.9 ft) at both the north location (Figure 4-30) and the south location (Figure 4-31) in early March 2005. This moisture is below the range of substantial surface E. During 2006 and 2007, the gradual drying of the soil profile at Pit 3 by deep percolation continued. By September 2007, the volumetric water content at 180 cm (5.9 ft) at both sites had returned to approximately 12 percent.

In 2000, TDR probes were installed in the operational covers of Pits 4 and 5 at depths ranging from 20 to 180 cm (0.7 to 5.9 ft). Precipitation events beginning in October 2004 infiltrated into the operational cover of Pit 4 and Pit 5, and percolated deeper than the deepest probe at 180 cm (5.9 ft) at Pit 4 in March 2005 (Figure 4-32) and at Pit 5 in April 2005 (Figure 4-33). Similar to Pit 3, the gradual drying of the soil profile continued in 2007. Because this moisture is below the range of substantial surface E, the gradual drying is most likely due to downward percolation.

In December 2000, TDR probes were installed in the final vegetated cover of the U-3ax/bl waste disposal unit at the Area 3 RWMS. Eight vertically arranged TDR probes were installed at four locations at depths ranging from 30 to 244 cm (1 to 8 ft). Measured soil water content values for one location (East Nest A) in the U-3ax/bl waste cover are shown in Figure 4-34. The TDR data indicate that the soil water content in the cover generally decreased over time as the vegetation on the cover grew. The precipitation events beginning in October 2004 infiltrated into the final cover of U-3ax/bl, but the moisture has been removed without percolating below the 244 cm (8 ft) deep sensor. Unlike the bare-soil operational covers on Pit 3, Pit 4, and Pit 5, the moisture at U-3ax/bl was removed by ET. The wetting front from the September 2007 precipitation only reached 30 cm (1 ft) deep as compared to 90 to 120 cm (3 to 4 ft) deep in the bare operational covers. The initial water content values are lower in the vegetated U-3ax/bl cover, so more precipitation water is stored per unit depth as the wetting front moves down. Vegetation is critical to the effectiveness of the U-3ax/bl cover. In the native environment, the area covered by plant material is about 12 percent. Obtaining 12 percent vegetative cover on the soil caps is dependent upon the seed germination success and seedling survival of native plants seeded or transplanted onto the soil cap. A quantitative analysis of the vegetative cover on the U-3ax/bl soil cap is conducted annually in the spring. The percent cover for the established U-3ax/bl cover has ranged from 20.2 percent in 2005, to 19.6 percent in 2006, to 10.6 percent in 2007.

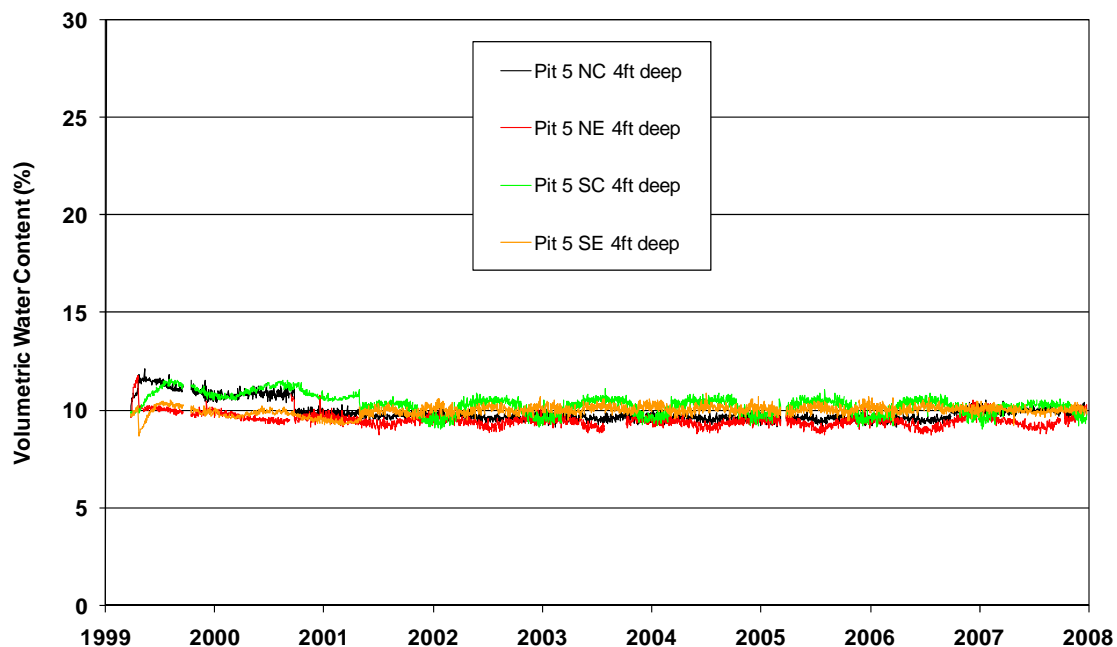


Figure 4-29 Soil Water Content in Pit 5 Floor Using Automated TDR System

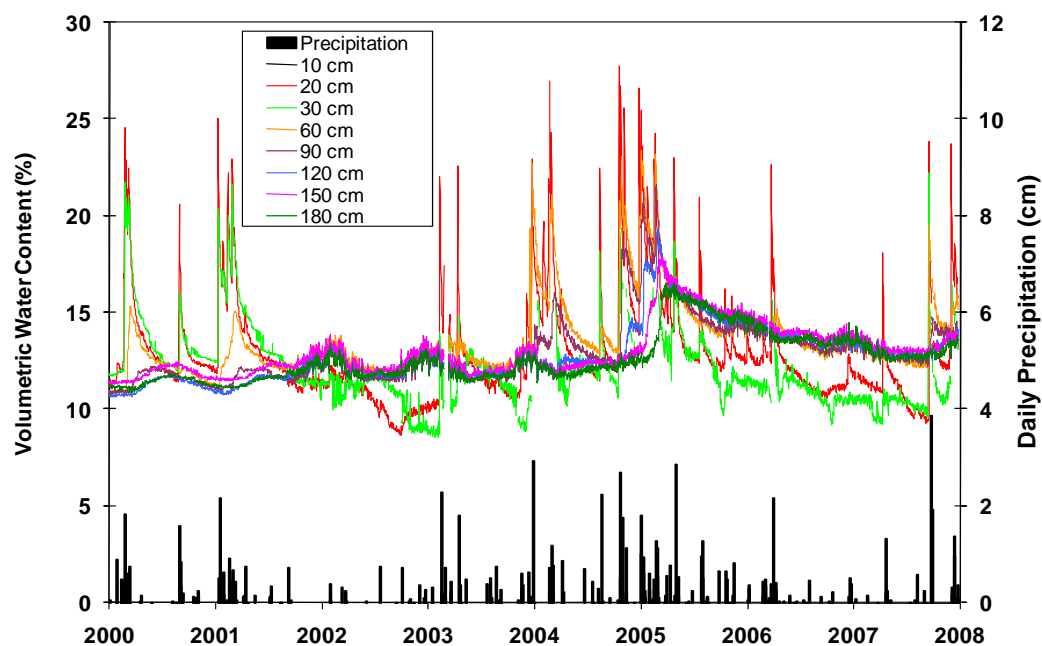


Figure 4-30 Soil Water Content in Pit 3 Waste Cover (North site) Using an Automated TDR System

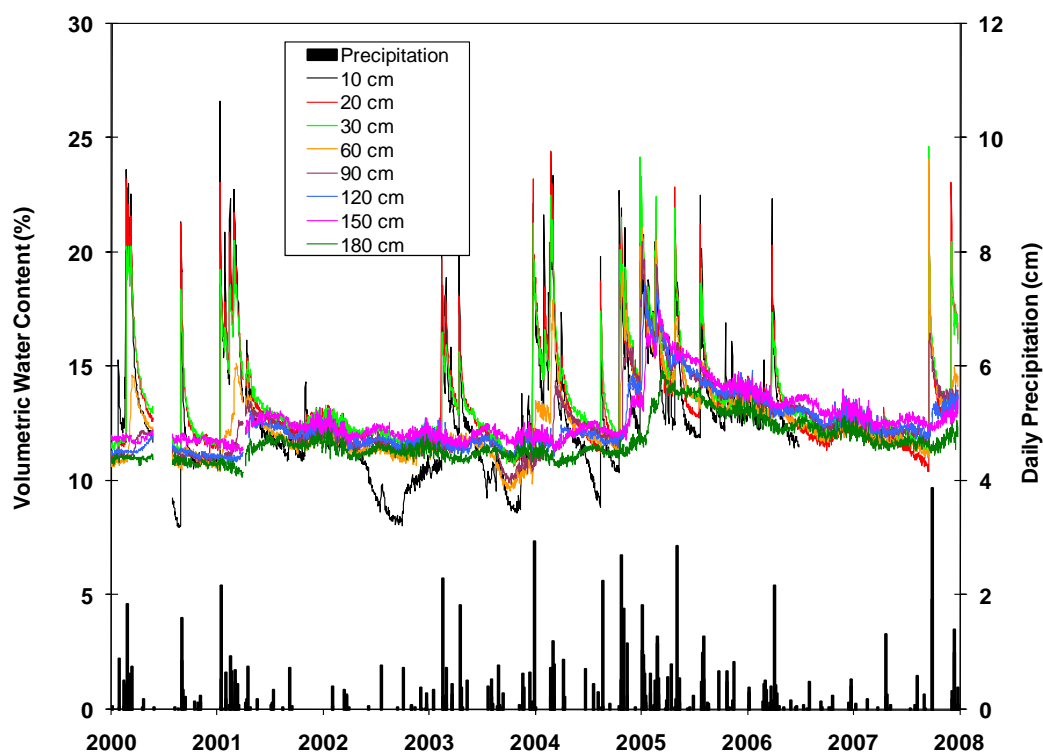


Figure 4-31 Soil Water Content in Pit 3 Waste Cover (South site) Using an Automated TDR System

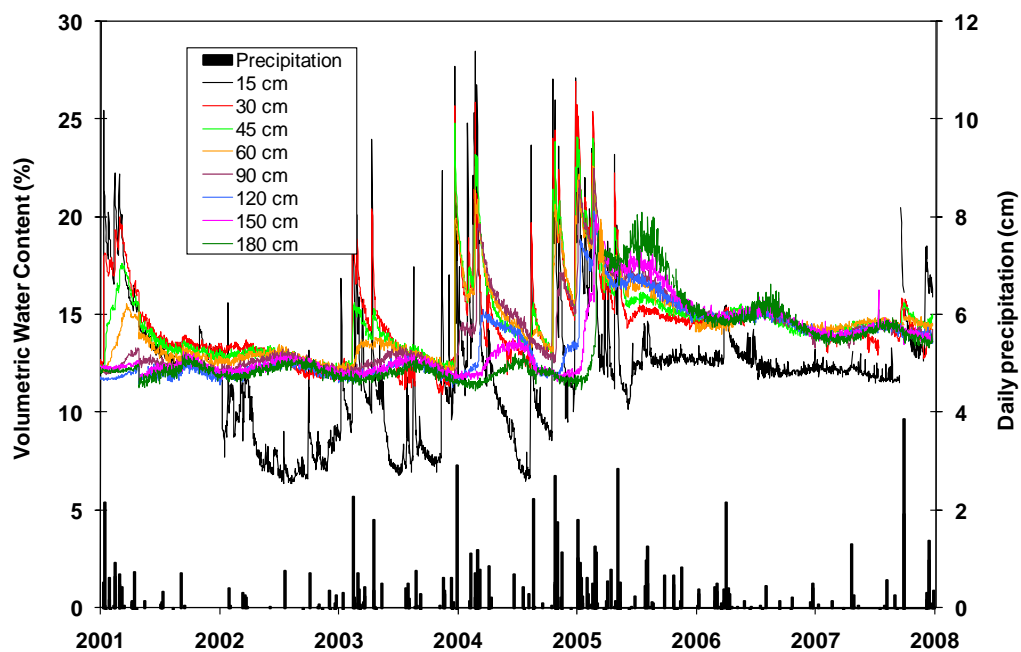


Figure 4-32 Soil Water Content in Pit 4 Waste Cover Using an Automated TDR System

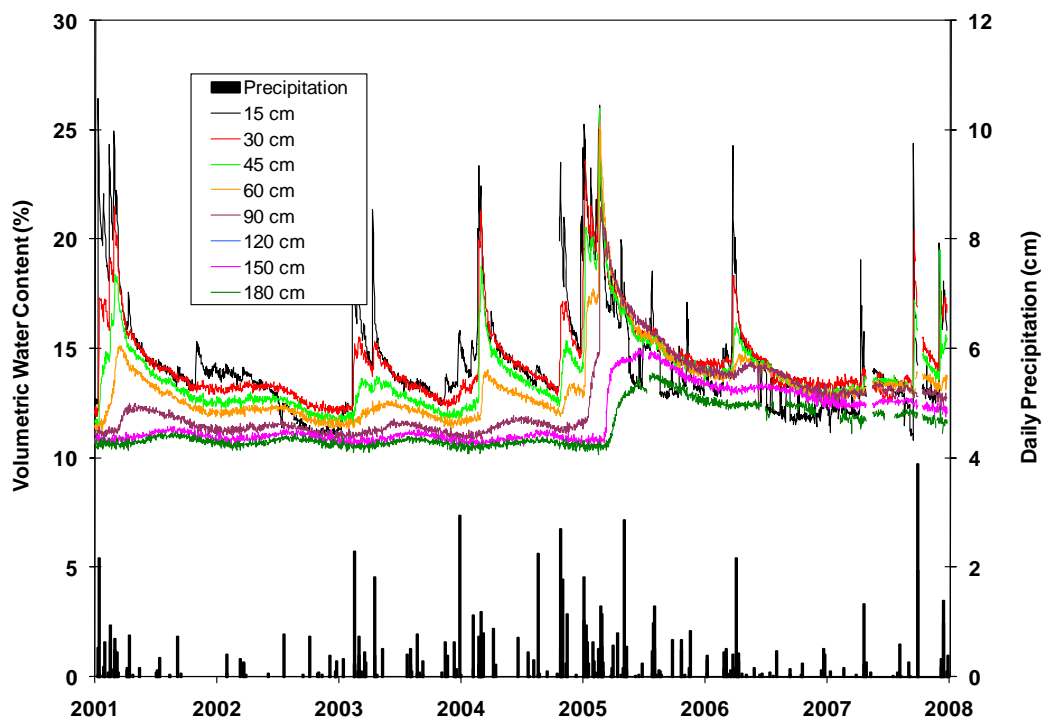


Figure 4-33 Soil Water Content in Pit 5 Waste Cover Using an Automated TDR System

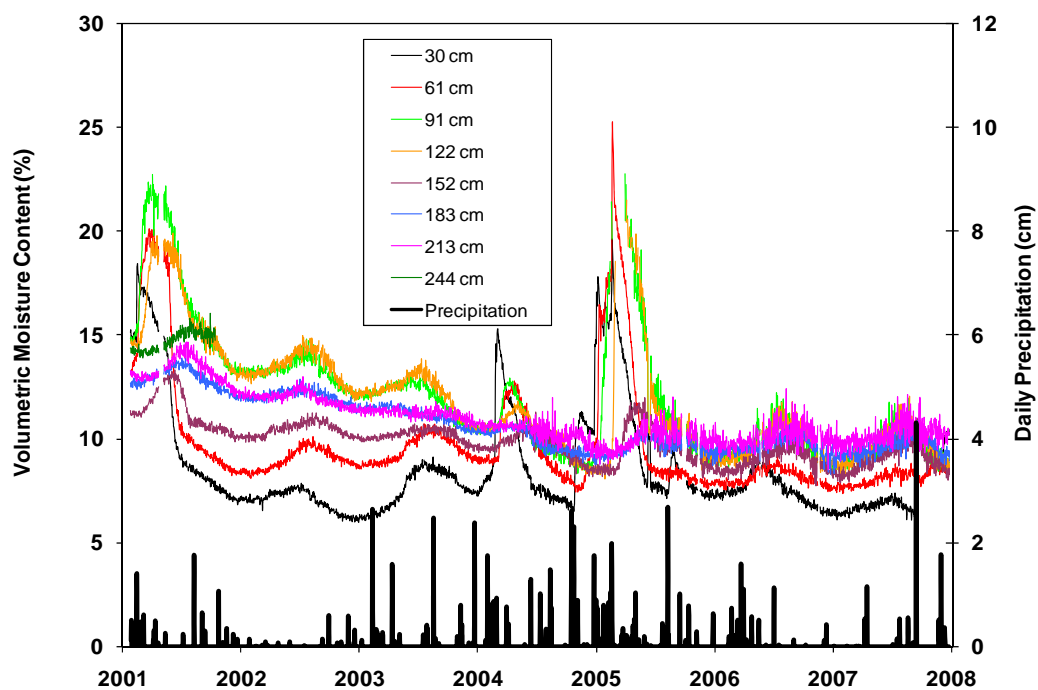


Figure 4-34 Soil Water Content in U-3ax/bl Waste Cover Using an Automated TDR System

4.6.5 Area 3 Drainage Lysimeter Facility

The Area 3 Drainage Lysimeter Facility is immediately northwest of the U-3ax/bl waste disposal unit at the Area 3 RWMS (Figure 3-1). This facility is designed to collect saturated gravity drainage from eight 3.05 m (10 ft) diameter by 2.44 m (8 ft) deep lysimeters. Each lysimeter is filled with native soil and packed to mimic the U-3ax/bl soil cover. Each lysimeter has eight TDR probes to measure moisture content depth profiles, paired with eight heat dissipation probes to measure soil water potential depth profiles. The probes are installed at 7.6 cm (0.25 ft), 15 cm (0.5 ft), 30 cm (1 ft), 61 cm (2 ft), 91 cm (3 ft), 122 cm (4 ft), 183 cm (6 ft), and 244 cm (8 ft) deep. Measured water content values at the bottom of the lysimeters and drainage from the lysimeters provide an indirect measure of potential drainage from the U-3ax/bl soil cover. The lysimeter facility was constructed to fulfill data needs including reducing uncertainty in the expected performance of monolayer-ET closure covers under various surface vegetation treatments and climatic change scenarios such as increased rainfall.

There are three surface vegetation treatments subject to two climate treatments on the lysimeters. The three surface vegetation treatments are bare-soil, invader species (primarily Russian thistle [*Salsoia iberica*], halogeton [*Halogeton glomerata*], and tumble mustard [*Descurania pinnata*]), and native species (primarily shadscale [*Atriplex confertifolia*], winterfat [*Krascheninnikovia lanata*], ephedra [*Ephedra nevadensis*], and Indian rice grass [*Achnatherum hymenoides*]). The climate treatments are natural precipitation and 3 times natural precipitation. The 3 times natural precipitation lysimeters receive natural precipitation and are irrigated with an amount equal to 2 times natural precipitation.

The eight lysimeters are identified as Lysimeter A through Lysimeter H. The irrigation and surface vegetation treatments to Lysimeters A, B, C, and D were not changed in 2007. Lysimeter A is bare soil with natural precipitation, Lysimeter B is bare soil with 3 times natural precipitation, Lysimeter C is invader species with natural precipitation, and Lysimeter D is invader species with 3 times natural precipitation (Table 1). Prior to 2006, Lysimeter E was native species with natural precipitation, Lysimeter G was invader species with natural precipitation, and Lysimeter H was invader species with 3 times natural precipitation. Prior to 2007, Lysimeter F was native species with 3 times natural precipitation.

The dry conditions after June 2005 resulted in the native plants on Lysimeter E dying and the surface being bare at the beginning of 2006. Lysimeters E, G, and H were seeded with native species and mulched with straw netting in February 2006. The original invader species on Lysimeters G and H were removed prior to seeding. Lysimeters E, G, and H were irrigated to promote seed germination. The 2006 precipitation at the Drainage Lysimeters was 104 mm (4.1 in.). The 2006 irrigation amounts were 226 mm (8.9 in.) at Lysimeters B, D, and F; 281 mm (11.1 in.) at Lysimeters E and G; and 318 mm (12.5 in.) at Lysimeter H. No irrigation was applied to Lysimeters A and C during 2006. Very few native plants were established on Lysimeters E, F, G, and H by January 2007, so Lysimeter E and F were seeded with native plants in January 2007, and container grown native plants (winterfat [*Krascheninnikovia lanata*] and Nevada Ephedra [*Ephedra nevadensis*]) were transplanted onto Lysimeters E, F, G, and H in May 2007. During 2007, Lysimeters E, F, G, and H were irrigated to promote seed germination and to establish the transplants. The 2007 precipitation at the Drainage Lysimeters was 134 mm (5.3 in.). The 2007 irrigation amounts were 274 mm (10.8 in.) at Lysimeters B and D, 311 mm (12.2 in.) at Lysimeters E and F, and 288 mm (11.3 in.) at Lysimeters G and H. No irrigation was applied to Lysimeters A and C during 2007. The 2007 lysimeter treatments are summarized in Table 1.

Table 1 Area 3 Drainage Lysimeter Treatment in 2007

Lysimeter	Climate	Precipitation (mm)	Irrigation (mm)	Surface Vegetation
A	Natural precipitation	134	0	Bare-soil
B	3 times natural precipitation	134	274	Bare-soil
C	Natural precipitation	134	0	Invader species
D	3 times natural precipitation	134	274	Invader species
E	Irrigation for seed germination and transplants	134	311	Native species
F	Irrigation for seed germination and transplants	134	311	Native species
G	Irrigation for transplants	134	288	Native species
H	Irrigation for transplants	134	288	Native species

There were 861 liters (227 gallons) of drainage from Lysimeter B during 2007. The equivalent depth of this drainage is 11.8 cm (4.6 in.). This drainage occurred from April 22, 2007, to July 30, 2007, and from October 3, 2007, to December 31, 2007, and is 29 percent of total precipitation and applied irrigation. There was no drainage from any other lysimeter during 2007. Drainage has only occurred from the irrigated lysimeters. Total cumulative drainage from each irrigated lysimeter is 67.9 cm (26.7 in.) from Lysimeter B, 5.8 cm (2.3 in.) from Lysimeter D, 29.3 cm (11.5 in.) from Lysimeter F, and 12.3 cm (4.8 in.) from Lysimeter H (Figure 4-35).

Figure 4-36 shows the total water storage for all eight lysimeters during the last 4 years. Water storage is calculated using TDR data. The two bare-soil lysimeters (Lysimeters A and B) have the highest water storage. Low plant surface cover and poor growth during 2007 resulted in lower ET and increased water storage in the other lysimeters.

4.6.6 Waste Cover Subsidence

Subsidence monitoring is conducted to ensure that subsidence features are repaired to prevent the development of preferential water migration pathways through the waste covers.

Subsidence monitoring also helps ensure that vadose zone monitoring data are representative of the entire RWMS. Typically as small depressions or cracks are observed in the covers, they are filled before large subsidence features develop. No large subsidence features were observed on the pit covers during 2007.

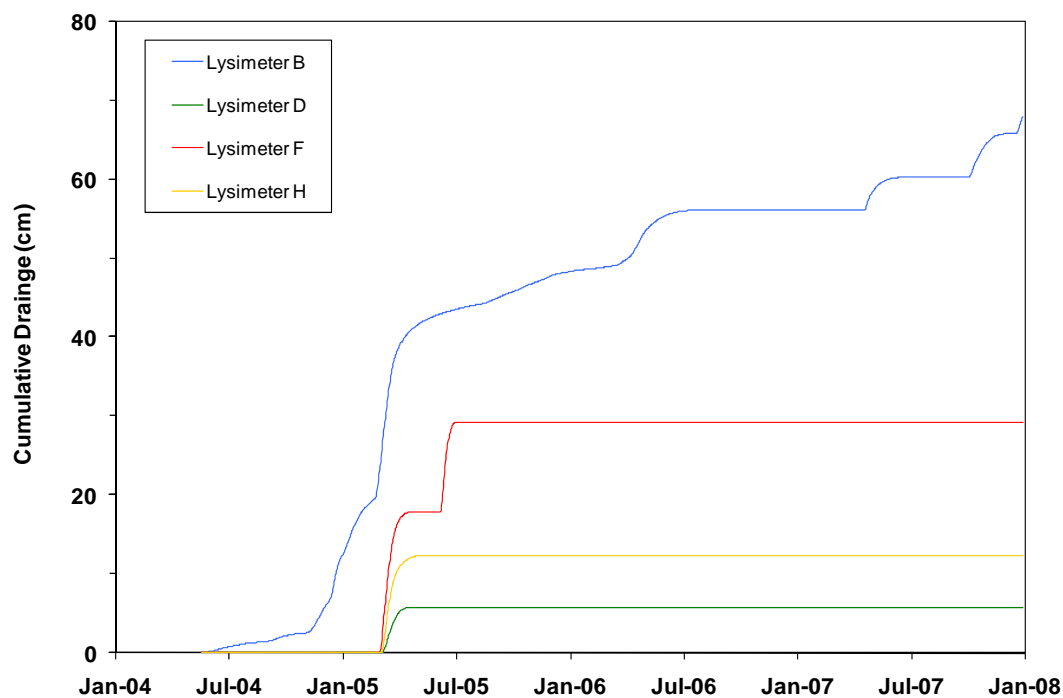


Figure 4-35 Cumulative Drainage from the Drainage Lysimeters

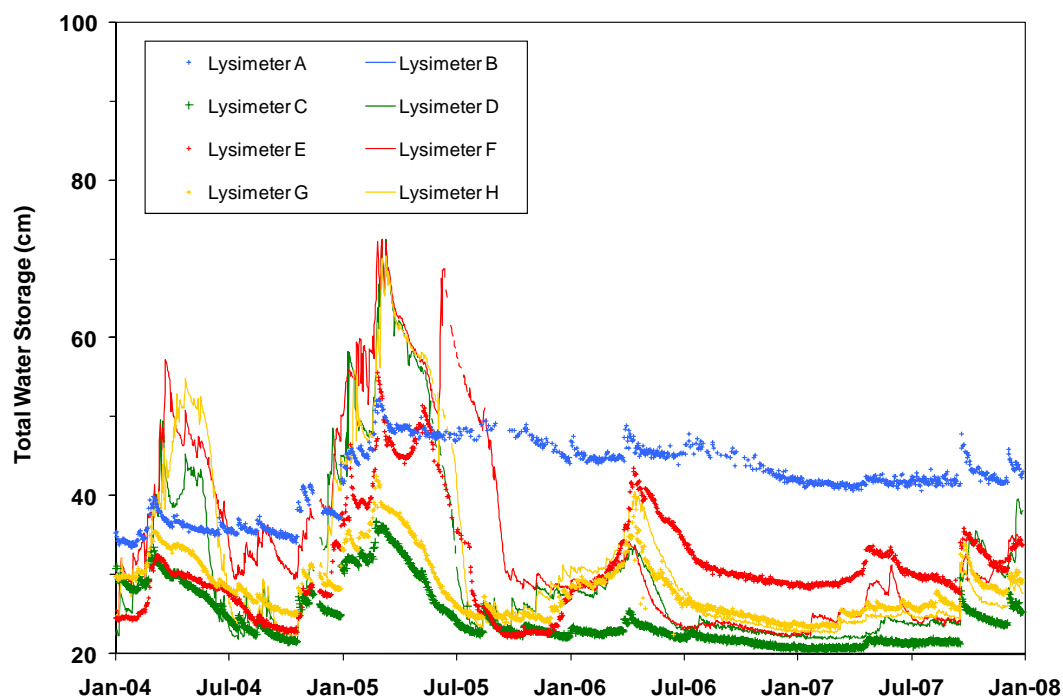


Figure 4-36 Soil Water Storage in the Drainage Lysimeters

4.6.7 Biota Monitoring Data

Plant and animal (biota) monitoring at the Area 3 RWMS and Area 5 RWMS help characterize and define trends in potential transport of radionuclides from buried waste thereby providing data to help demonstrate that projected releases of radionuclides to the environment are within PA projections. Tritium is the predominant radionuclide observed due to its high mobility as tritiated water. The primary mechanisms that transport tritium upward through waste covers and into the atmosphere are gaseous diffusion, gaseous advection, bioturbation, plant uptake and transpiration, and soil E. Sampling water from plants and animals that live on waste covers provides a direct measure of tritium uptake. Analysis of plant and animal tissues for gamma-emitting radionuclides, ^{90}Sr , and alpha-emitting radionuclides provides information on potential biotic intrusion into the waste and uptake of radionuclides.

Biota sampling took place August 27–29, 2007. A total of three plants, five small mammals (composited into one sample), and three samples of soil excavated by small mammals or ants were sampled from the U-3ax/bl cover at the Area 3 RWMS. Five plants, one small mammal, and three soil samples from small mammal burrows or ant nests were sampled from the Area 5 RWMS (Figure 4-37, Figure 4-38, Table 2, Table 3, and Table 4). Only one small mammal was captured after 192 trap-nights due to low availability of small mammals at the Area 5 RWMS. As a record of bioturbation, small mammal burrows were recorded on the U-3ax/bl cover (Figure 4-39 and both small mammal burrows and ant nests were recorded on portions of the Area 5 RWMS (Figure 4-40). Control plant, small mammal, and soil samples were collected in Area 22 within 500 m (1,640 ft) of the Army Water Well to provide background radionuclide concentration data for biota (Table 2, Table 3, and Table 4). Each of the control location samples were a composite of three each for plant, small mammal, and soil samples.

Water was extracted from biota samples by distillation and submitted to a subcontract lab for analysis of tritium content using liquid scintillation. Tritium concentrations are displayed in Figure 4-41 and Figure 4-42 and are listed in Table 2 and Table 3. Due to the very low water content, no tritium results were possible from the soil samples. Soil and dried tissue samples were submitted to a subcontract lab for analysis of gamma-emitting radionuclides, ^{90}Sr , ^{241}Am , and plutonium.

Detected man-made radionuclides are listed in Table 2, Table 3, and Table 4. Tritium was detected in all RWMS biota samples, and tritium concentrations were much higher than any other detected radionuclide. Levels of radionuclides, except tritium, in samples from the Area 5 RWMS were not different from the concentrations measured at the control site (Table 2, Table 3, and Table 4). Soil, plants, and animals from the U-3ax/bl cover had more detections of radionuclides and had concentrations generally higher than those from the control site (Table 2, Table 3, and Table 4). Given the Area 3 RWMS proximity to diffuse sources of radionuclides from historical atmospheric nuclear testing, it is likely that wind-blown radionuclides from these areas are the source in RWMS vegetation rather than the waste.

Bioturbation of the soil from small mammal or ant burrowing activity is displayed in Figure 4-39 and Figure 4-40. Trapping and removal of small mammals from the Area 3 RWMS U-3ax/bl cover has taken place over the past three years. Although this activity has taken place, the density of small mammal burrows (one or cluster of burrow entrances) on the cover was about 1 per 170 m² or 0.006 burrows per m² and was fairly evenly distributed across the cover (Figure 4-39). Burrows on the Area 5 RWMS are concentrated on the side slopes of the covers. Management (removal) of vegetation on the Area 5 RWMS has resulted in very low densities of small mammals. Most burrow entrances surveyed appeared to be inactive (e.g., spider webs

across entrance or no signs [footprints or droppings] observed). Differences in burrow densities were clear between older covers (e.g., P01U, P02U, T02U, and T04U) versus relatively new covers (e.g., P04U and P05U) (Figure 4-40). Radionuclide concentrations in small mammal or ant excavated soil did not indicate that these animals had intruded into the waste.

Data on tritium in plants sampled from the Area 3 and Area 5 RWMS over the past nine years is presented in Figure 4-41. As limited small mammal sampling has occurred on the RWMS, only tritium data from 2005 and 2007 are available (Figure 4-42). High variability within years makes differences between years negligible. Tritium uptake by the biota is due to its high mobility as tritiated water. Tritiated water moves upward through waste covers by gaseous diffusion, gaseous and liquid advection, plant uptake and transpiration, and soil E.

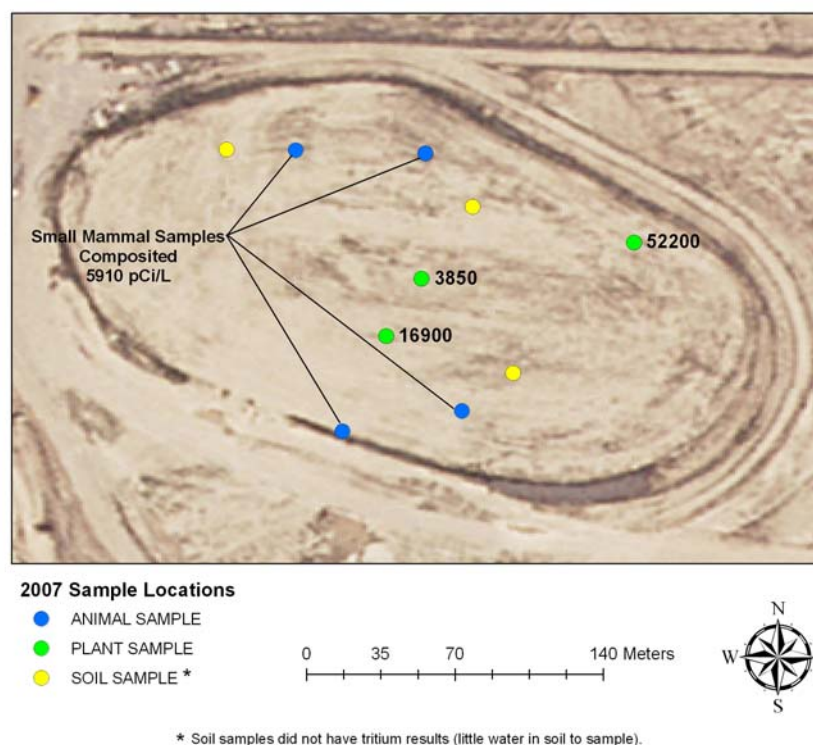


Figure 4-37 Biota and Soil Sample Locations on the U-3ax/bl Cover with Tritium Results

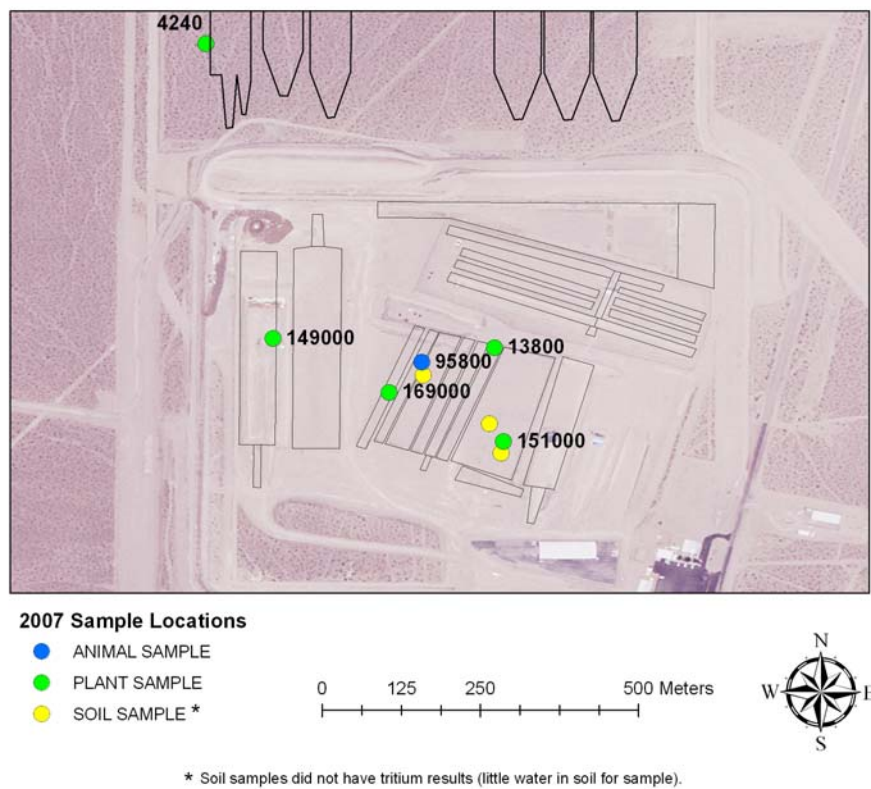


Figure 4-38 Biota and Soil Sample Locations at the Area 5 RWMS with Tritium Results

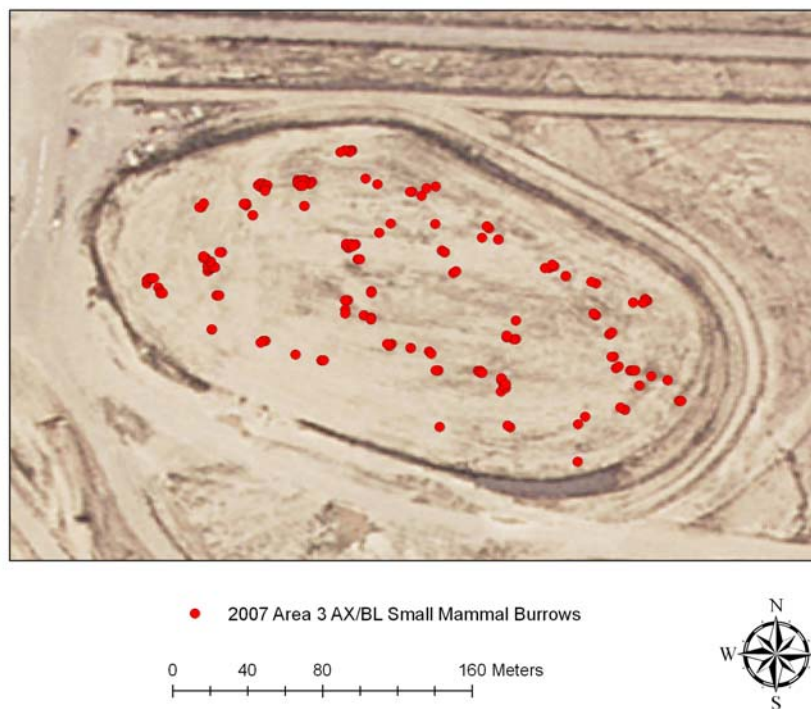


Figure 4-39 Small Mammal Burrows on the U-3ax/bl Cover, May 2007

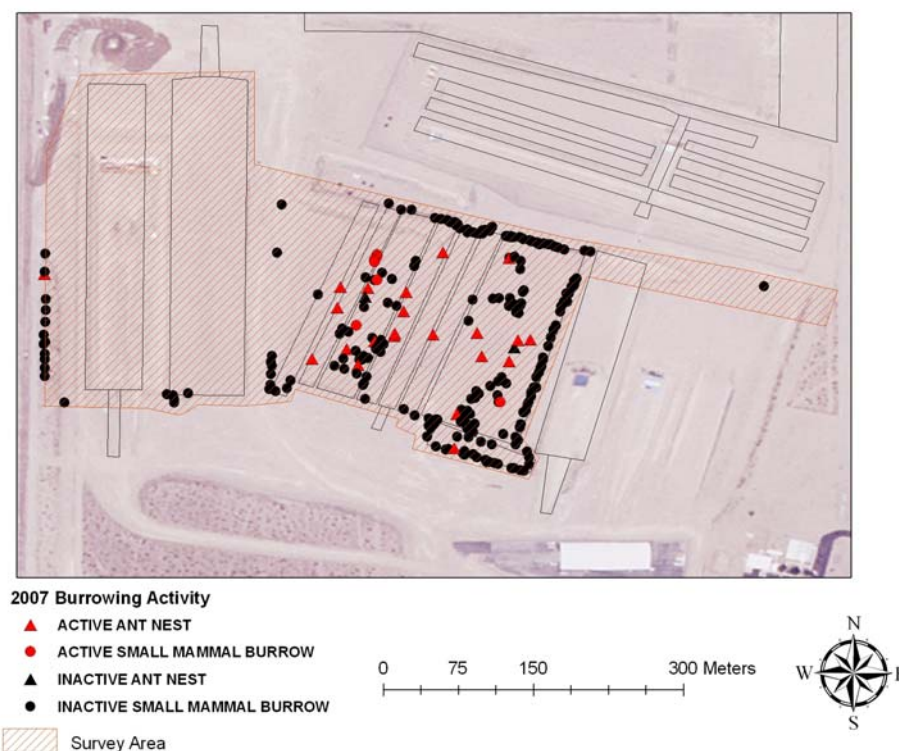


Figure 4-40 Small Mammal and Ant Burrowing Activity at the Area 5 RWMS, August 2007

Table 2 Radionuclide Results for Vegetation Samples

Sample ID	Location	^3H (pCi/L)	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	$^{239+240}\text{Pu}$ (pCi/g)
Four-wing Saltbush	Area 3 RWMS	52200	0.08	0.08	-0.0008
Shadscale Saltbush #1	Area 3 RWMS	3850	0.17	0.02	0.0289
Shadscale Saltbush #2	Area 3 RWMS	16900	0.37	-0.01	0.0155
Four-wing Saltbush	Area 5 RWMS	151000	-0.03	0.02	0.0035
Cattle Saltbush #1	Area 5 RWMS	169000	0.01	0.01	0.0030
Cattle Saltbush #2	Area 5 RWMS	13800	-0.02	-0.02	0.0014
Russian Thistle #1	Area 5 RWMS	149000	-0.02	0.01	0.0099
Russian Thistle #2	Area 5 RWMS	4240	0.01	-0.01	0.0061
Creosote Bush	Control	187	0.04	-0.02	0.0036

Green-Shaded results are considered detected (results greater than sample-specific MDC)

Table 3 Radionuclide Results for Animal Samples

Sample	Location	^3H (pCi/L)	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	$^{239+240}\text{Pu}$ (pCi/g)	^{241}Am (pCi/g)
Kangaroo Rats (composite of 5)	Area 3 RWMS	5910	0.11	0.06	0.1120	0.0221
Kangaroo Rat (one animal)	Area 5 RWMS	95800	0.00	0.08	-0.0007	0.0005
Wood Rat (composite of 3)	Control	80.9	0.03	-0.02	0.0023	-0.0003

Green-Shaded results are considered detected (results greater than sample-specific MDC)

Table 4 Radionuclide Results for Soil Samples

Sample	Location	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	^{152}Eu (pCi/g)	^{238}U (pCi/g)	$^{239+240}\text{Pu}$ (pCi/g)	^{241}Am (pCi/g)
Ant Nest	Area 3 RWMS	0.262	0.0663	0.347	0.884	0.0491	0.00741
Burrow 1	Area 3 RWMS	-0.117	0.00536	0.0316	1.31	0.0248	0.00012
Burrow 2	Area 3 RWMS	-0.212	0.0319	-0.0466	0.994	0.0143	0.00414
Ant Nest	Area 5 RWMS	-0.172	-0.00545	-0.0578	1.14	0.00452	-0.00349
Burrow 1	Area 5 RWMS	0.344	-0.00334	-0.0456	0.777	0.00325	0.00121
Burrow 2	Area 5 RWMS	0.118	0.0149	-0.0128	1.13	0.00558	0.006
Composite of 3 Burrows	Control	-0.268	0.028	0.00288	0.493	0.00237	0.00521

Green-Shaded results are considered detected (results greater than sample-specific MDC)

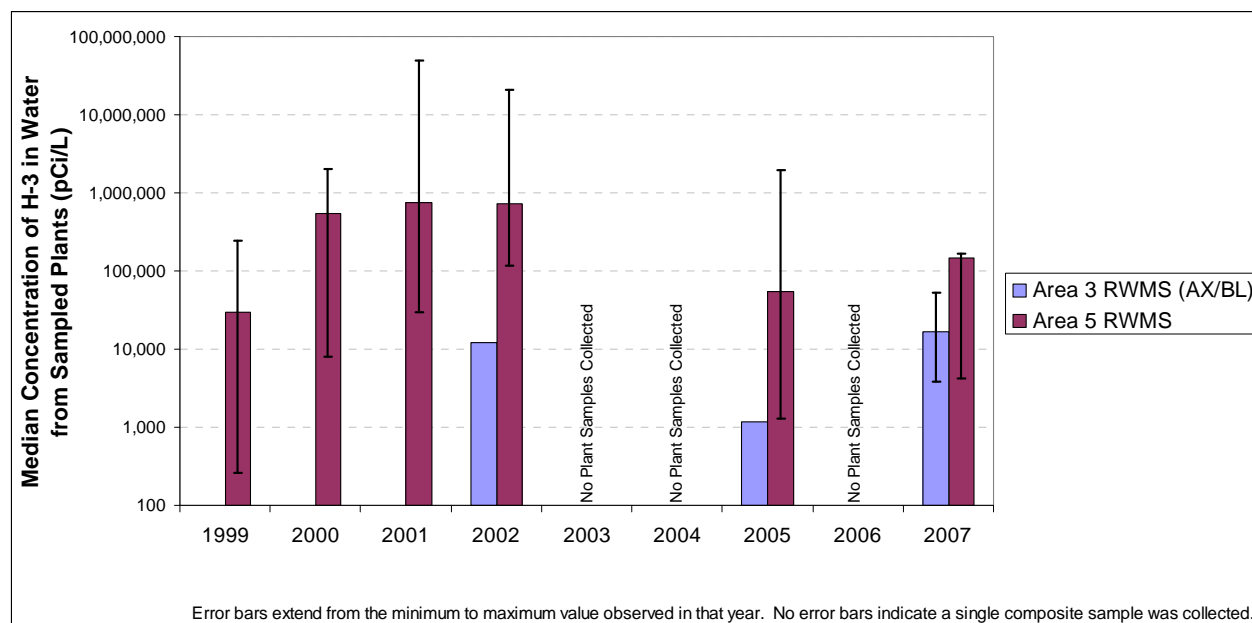


Figure 4-41 Median Tritium Concentration in RWMS Vegetation, 1999–2007

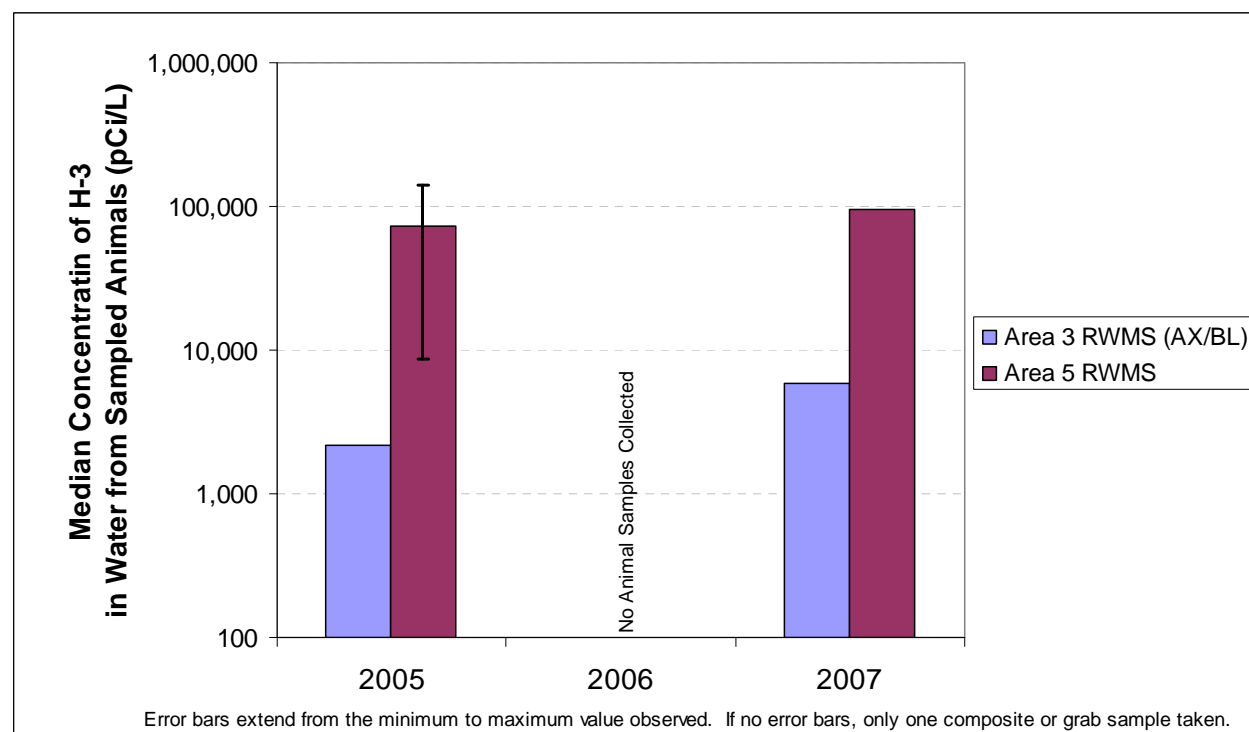


Figure 4-42 Tritium Concentration in RWMS Animal Samples, 2005–2007

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5.0 CONCLUSIONS

The 2007 environmental and operational monitoring data from the Area 3 and Area 5 RWMSs indicate that these facilities are performing as expected for the long-term isolation of buried waste. Direct radiation exposure data indicate a rate that is well below any dose of concern; air monitoring data indicate that concentrations of radioactive materials in air remain below any concentrations of concern. Groundwater and vadose zone monitoring data indicate that the groundwater beneath the Area 5 RWMS is unaffected by the waste disposal operations. Soil gas monitoring data at GCD-05U indicate little natural migration of tritium away from the waste at this disposal borehole. Vadose zone monitoring data indicate that vegetation prevents infiltrating precipitation from percolating deep into the soil by returning the moisture to the atmosphere by ET. Long-term vadose zone monitoring data from the weighing lysimeters indicate no drainage through the bottoms of the vegetated lysimeters. Biota monitoring data show tritium uptake but provide no evidence that plants or animals have intruded into the waste. All 2007 monitoring data indicate that the Area 3 and Area 5 RWMSs are performing within expectations of the model and parameter assumptions for the facility PAs.

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